Report No. SFIM-AEC-ET-CR-99051

UXO TECHNOLOGY DEMONSTRATION PROGRAM AT JEFFERSON PROVING GROUND

PHASE IV

U.S. Army Environmental Center

Naval Explosive Ordnance Disposal Technology Division

May 1999

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing Instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports. 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20603.

1. AGENCY USE ONLY *(Leave Blank)*

2. REPORT DATE
May 1999

3. REPORT TYPE AND DATES COVERED
August 1998 – November 1998

4. TITLE AND SUBTITLE
UXO Technology Demonstration Program at Jefferson Proving Ground, Phase IV

5. FUNDING NUMBERS

6. AUTHOR(S)

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10. SPONSORING/MONITORING AGENCY REPORT NUMBER
SFIM-AEC-ET-CR-99051

11. SUPPLEMENTARY NOTES
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12a. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
The fourth in a series of Unexploded Ordnance (UXO) Technology demonstrations at Jefferson Proving Ground, Madison IN, was conducted April through November 1998. An existing controlled site was modified to incorporate a "self test" area where selected demonstrators could collect data on buried ordnance and non-ordnance targets. Target position, depth, type, and orientation was provided as government furnished information. Afterwards, a "blind test" site was established to evaluate demonstrator capabilities to discriminate ordnance from non-ordnance.

The performance of 10 discrimination companies and 1 remediation company is documented in this report. In general, a better than expected performance of discrimination was observed but not to the degree required to make a significant impact on range cleanup. Technology initiatives should continue in the future to fund detection and discrimination schemes and to periodically conduct blind testing as a confirmation of demonstrator capabilities.

14. SUBJECT TERMS
Discrimination, Installation Restoration, Remediation, Unexploded Ordnance, UXO

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF THIS ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	**Unclassified**	**Unclassified**	**Unlimited**

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ACKNOWLEDGEMENT

Without the cooperation and guidance of the following individuals and organizations, this report would not have been possible: Ms Denice Forsht, Mrs Mary Sherlock, and Mr. Andy Pederson (NAVEODTECHDIV), Ms. Carol Richardson (Tetra Tech), and the people at JUXOCO.

Unfortunately space considerations prevent the acknowledgement of all persons who have contributed, but their help and guidance are appreciated.

List of Abbreviations, Acronyms, and Symbols

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Abbreviations and Acronyms:

AEC	Army Environmental Center
ADAM	Area-Denial Artillery Munition
AMAT	AntiMATerial
AP	Army Piercing
APERS	AntiPERSonnel
BLU	Bomb Live Unit
BRAC	Base Realignment And Closure
CBU	Cluster Bomb Unit
DARPA	Defense Advanced Research Projects Agency
DDESB	Department of Defense Explosive Safety Board
DoD	Department of Defense
DWP	Demonstrator Work Plan
EM	ElectroMagnetic
EOD	Explosive Ordnance Disposal
FAR	False Alarm Rate (# of false alarms / hectare)
FM	Field Manual
FN	False Negative
FP	False Positive
GIS	Geographical Information System
GPR	Ground Penetrating Radar
GPS	Global Positioning System
HE	High Explosive
HEAT	High Explosive Anti-Tank
HEP	High Explosive Plastic
JPG	Jefferson Proving Ground
MAG	MAGnetometer
MOE	Measure Of Effectiveness
NAVEODTECHDIV	Naval Explosive Ordnance Disposal Technology Division
NEW	Net Explosive Weight
N_u	Non-Ordnance Declared as "Unknown"
O_u	Ordnance Declared as "Unknown"
P_D	Probability of Detection (# of buried items detected / # of buried items emplaced
POC	Point Of Contact
RPG	Rocket Propelled Grenade
SHERP	Safety, Health, and Emergency Response Plan
TDEM	Time Domain Electromagnetic
TN	True Negatives
TNOB	Total Non-Ordnance Buried
TOB	Total Ordnance Buried
TP	True Positives
UXO	UneXploded Ordnance

WES	Waterways Experiment Station (Corps of Engineers)
WP	White Phosphorous (screening smoke)

Units:

Hectare	~ 2.5 acres (10,000 square meters)
1 gamma (γ)	10^{-5} gauss , 10^{-9} tesla (1 nT)
Millivolt (mV)	10^{-3} volts
Kilogram (kg)	10^{3} grams , 2.2 pounds (lb)

EXECUTIVE SUMMARY

In 1993, Congress mandated that the U.S. Army conduct a program at Jefferson Proving Ground (JPG), near Madison, Indiana, to demonstrate and evaluate systems and technologies that can be used to detect, identify, and remediate buried unexploded ordnance (UXO). Since this time, four separate and distinct Technology Demonstration Phases have been conducted. JPG Phases I, II and III established a trend towards improvements in UXO detection as “mag and flag” approaches conveyed to more sophisticated approaches that employed multi-sensors, precise integrated navigation, and advanced data processing. Despite this progress, state-of-the-art UXO detection technology is plagued with high false alarm rates, attributed to the inability to distinguish UXO from man-made clutter. Assuming that anomalies can be detected, discrimination is needed to classify UXO and non-UXO to reduce the costs associated with excavating non-ordnance.

In JPG Phase IV, the JPG test site was specifically modified for the evaluation of UXO *discrimination* technology, where vendors were allowed to interrogate identified anomaly locations and gather dense data sets in an effort to assess their capability to discriminate ordnance and non-ordnance clutter. As such, the JPG Phase IV performance goals were set in place as follows:

- 95% effective discrimination of UXO targets that range in size from 20 mm projectiles to 155mm projectiles, and
- 75% effective discrimination of comparable-sized non-UXO (clutter) targets.

The secondary focus of the JPG demonstrations was to assist site restoration managers in:

- Displaying the performance of current state-of-the-art technology and capabilities.
- Serving as a baseline for future discrimination exercises under the test conditions stated.[1]
- Identify area of emphasis for future R&D efforts

Phase IV ...

In past JPG demonstrations, the ability to detect subsurface ordnance was critical to the success of UXO site characterization and remediation efforts. During those demonstrations it became evident that there was a problem determining the difference between ordnance and non-ordnance buried targets – “Another issue with detection performance is that a system with a high probability of detection may be of little practical value if it generates an excessive number of target reports that do not correspond to ordnance.”[2]

A two phased approach was used to fulfill the goals of the program. The first was an enhancement phase or self-test phase. Demonstrators were encouraged to develop new sensors and/or procedures and test them on buried targets at the JPG 80-acre site.

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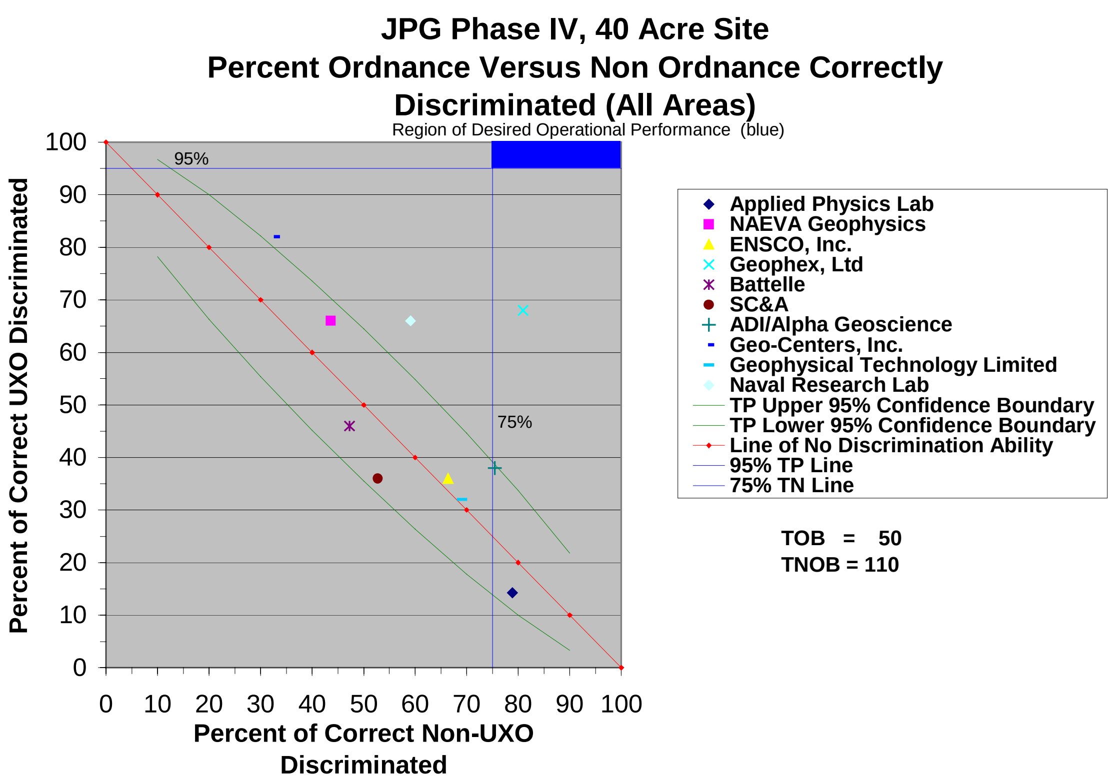
[1] To distinguish between full, intact, inerted, non-degaussed, hand emplaced ordnance and man-made, ferrous content, hand emplaced debris.

[2] U.S Army Environmental Center, Naval Explosive Ordnance Disposal Technology Division, Report No. SFIM-AEC-ET-CR-97011, “UXO Technology Demonstration Program at Jefferson Proving Ground, Phase III (April 1997)

All information about the buried targets, including 23 ordnance and 46 non-ordnance targets, was provided to the demonstrators. In addition, representative samples of the targets (except 76 mm) were available for vendor evaluations. Six demonstrators were evaluated by a government group of experts and, based upon their proposals, were chosen to participate in the self-test. After the conclusion of the self-test phase, a blind test phase commenced on the 40-acre site. Ten demonstrators, including the original 6 from the self-test phase, performed a discrimination survey of 160 targets (50 ordnance and 110 non-ordnance targets). During the blind test phase, demonstrators were told that a previous survey had uncovered potential burial sites of UXO and those locations had been marked on the ground. The only information provided to the demonstrator was horizontal (x, y) position (marked with a flag) and the fact that previous excavation attempts had resulted in more non-ordnance being recovered than ordnance.

Results of Phase IV show there is a developing capability to distinguish ordnance and non-ordnance. One of the ten demonstrators[3] showed a better than 75% ability to discriminate non-ordnance from ordnance while maintaining a relatively high TP rate. Though this is an important first step, no demonstrator was able to meet the desired performance level, 95% TP and 75% TN, established before the demonstrations began.

Graph ES-1. Discrimination Effectiveness



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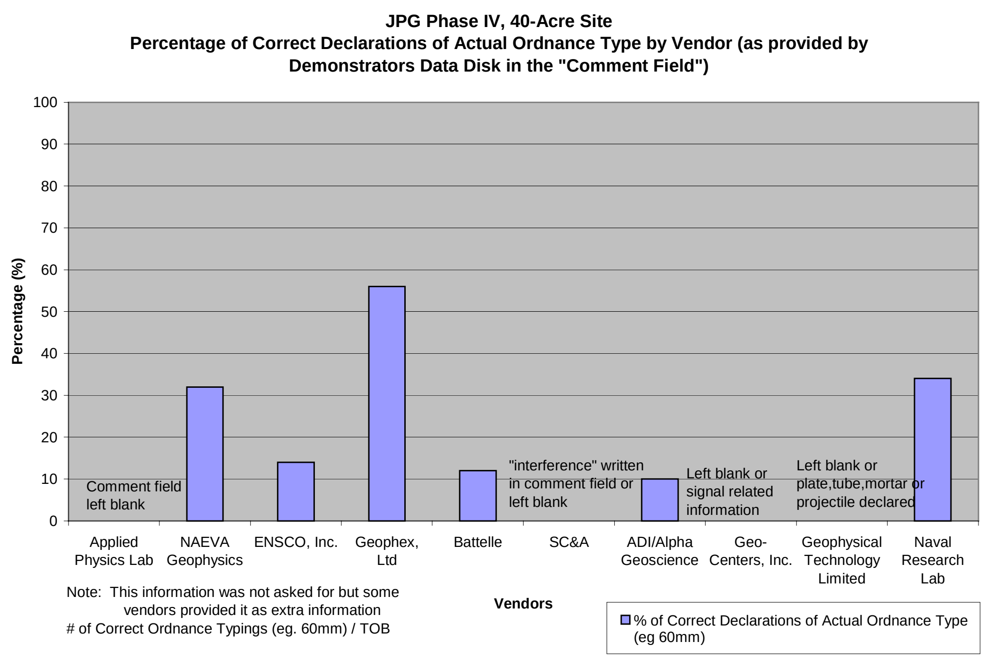
[3] 10 discrimination demonstrators, 1 remediation demonstrator

Graph ES-1 distinctly shows some demonstrators had the ability to tell the difference between ordnance targets and non-ordnance targets given the conditions of the test.

Demonstrators were asked to not only determine ordnance from non-ordnance, but to declare what kind of ordnance they detected. Graph ES-2 summarizes these results. Geophex was able to correctly determine the ordnance item (e.g. 60mm mortar, 20mm projectile, etc.) over 55% of the time. The Naval Research Lab and NAEVA Geophysics were able to correctly identify the kind of ordnance over 30% of the time. This is a significant increase in discrimination capability not seen in previous demonstration phases.

Other graphs were generated detailing performance in declaring depth, weight, size, confidence, and these are located in the main body of the report. In addition to the demonstration results, Appendix F contains the full phenomenological study performed by the Waterways Experiment Station (WES). This study provides details on the field environment that may influence vendor performance.

Graph ES-2. Percentage of Correct Declarations of Actual Ordnance Types by Vendor



Raw data was collected from all the vendors and released to the Joint UXO Center of Excellence (UXOCOE) web site (www.denix.osd.mil/UXOCOE) along with the ground truth. Providing data and ground truth to the public germinates new ideas and concepts; fostering partnerships between industry, government, and academia.

Results from Phase IV, as well as previous phases, lead to the following recommendations:

- New and continued developments in sensor technologies and processing are needed.
- Future detection and discrimination exercises should be conducted as new capabilities are identified.
- Economic incentives should be incorporated into remediation contracts to stimulate continued development.
- That “real world” ordnance and clutter target sets be acquired and made available to technology developers.
- Establishment of other DoD test areas in geographically diverse environments to test sensor and processing performance due to geology, vegetation, and climate variations.

1.0 INTRODUCTION

In 1993, Congress mandated that the U.S. Army conduct a program at Jefferson Proving Ground (JPG), near Madison, Indiana, to demonstrate and evaluate systems and technologies that can be used to detect, identify, and remediate buried unexploded ordnance (UXO). The U.S. Army Environmental Center (USAEC), in the Edgewood Area of Aberdeen Proving Ground, Maryland, was designated as the program manager. USAEC tasked the Naval Explosive Ordnance Disposal Technology Division (NAVEODTECHDIV), Indian Head, Maryland, with the technical lead in program execution.

This document is divided into five sections.

- Section 1.0 provides the introduction and a historical synopsis of JPG Phases I, II, III technology demonstrations and their results.
- Section 2.0 describes the JPG Phase IV Program Goals and Objectives, the Technology Demonstration (TD) methodologies and technical approach, site operations and procedures, the selection process for demonstrators, the procedures followed for the demonstrations, and the quality assurance procedures.
- Section 3.0 presents the performance evaluation methodology.
- Section 4.0 documents the analysis and results of target discrimination and excavation demonstrations.
- Section 5.0 presents the conclusions and recommendations.

The need for this program….

UXO detection and clearance technology deficiencies came to the forefront in our nation's newspapers with the public's realization that the base realignment and closure (BRAC) process would not result in the immediate turnover, to the public, of former Department of Defense (DOD) properties. A legacy of decades old unexploded projectiles, rockets, bombs, and missiles, and even cannonballs from the past century, restricts unlimited public use and access to these lands. In addition, active DOD installations considering alternative land uses face unknown hazards because of poor record keeping on past ordnance usage. Installation managers need to know the capabilities and limitations of UXO detection and clearance technologies to perform effective site remediation.

There is an enormous demand to characterize the UXO hazards on large tracks of land. The following excerpt is from a DOD Explosive Safety Board (DDESB) report[1]:
"Contamination of land and sea from unexploded ordnance has grown to a level where it now presents a serious problem in the United States. The contamination prevents civilian land use, threatens public safety and causes environmental concerns. Estimates indicate that over 15 million acres in the United States may contain some level of UXO contamination, at about 1,500

[1] Report Of The Defense Science Board Task Force ON UNEXPLODED ORDNANCE (UXO) CLEARANCE, ACTIVE RANGE UXO CLEARANCE, AND EXPLOSIVE ORDNANCE DISPOSAL (EOD) PROGRAMS, April 1998

different sites. This figure does not include the acreage of UXO contamination undersea. DOD's responsibilities include providing UXO site clean-up project management, assuring compliance with federal, state and local laws and environmental regulations, assumption of liability, and appropriate interactions with the public. DOD has no specific UXO remediation policy, goals or program. Current UXO site remediation efforts are based on decades-old technology and use several procedures that are inefficient, labor-intensive and costly. Because the suspect sites have not been surveyed, there is great uncertainty about the actual size of the UXO problem. However, even if only 5% of suspect acreage need cleanup, remediation costs would still be high (possibly exceeding 15 billion dollars) and times would be long (possibly exceeding several decades to complete) using current technologies. UXO site remediation in the United States currently is being funded at about $125M per year, excluding special clean-up programs (such as the on-going clean-up at Kaho'olawe, which has funding projected to total about $400M."

Past History…earlier work[2]

JPG Phase I and II. In the first two phases of these demonstrations, JPG Phase I and II conducted in 1994 and 1995 respectively, inert ordnance was emplaced at two JPG sites: a 16 hectare (40 acre) site established for ground-based technology demonstrations and another 32 hectare (80 acre) site established for airborne technology demonstrations. All ordnance locations were recorded and available for evaluation purposes, but were not accessible to the technology demonstrators. There were 29 demonstration systems in JPG Phase I. The data collected from Phase I was compared to the known (baseline) target data, and a technical report was published in December 1994. From May through September 1995, Phase II of the program was conducted in a similar manner as Phase I, and 17 additional or upgraded systems were demonstrated. JPG I and II showed that airborne platforms and ground penetrating radar (GPR) sensors did not perform well under the test conditions at JPG. Demonstrators who used a combination of sensors (electromagnetic induction and magnetometry) had the best results at JPG I and II. Data collected from Phase II was again compared to the known (baseline) target data, and a technical report was published in June 1996.

Some performers in Phase II detected over 80 percent of the ordnance, but they also reported three to twenty times more targets (false alarms) than actual ordnance. A major cost factor in remediating UXO properties is the inability to distinguish ordnance from prevalent clutter, either ordnance-related debris or residue associated with farming. Excavation demonstrations of remotely operated systems were also demonstrated during the first two Phases. Excavator's efficiency to unearth ordnance, (<5%), significantly lagged the ability of vendors to detect and mark targets. This means that for every 20 targets detected, 1 is excavated using the same time frame. Hence, excavation of detected anomalies consumes the greatest time and thus continues to drive the cost of UXO remediation efforts.

JPG Phase III. In 1996, Congress authorized a third phase of the program. JPG Phase III was conducted in a similar manner as Phases I and II, but the overall program goals were expanded. As in Phases I and II, all ordnance locations were recorded and available for

[2] U.S Army Environmental Center, Naval Explosive Ordnance Disposal Technology Division, Report No. SFIM-AEC-ET-CR-97011, "UXO Technology Demonstration Program at Jefferson Proving Ground, Phase III (April 1997)

evaluation purposes, but were not accessible to the technology demonstrators. The 16-hectare site was further subdivided into four realistic UXO scenarios. The scenarios established were an (1) Aerial Gunnery Range, (2) Artillery and Mortar Range, (3) Grenade and Submunition Range (3), and (4) an Interrogation and Burial Area. Demonstrators were allowed to tailor the sensitivity of their sensor(s) to the anticipated UXO target set for a specific scenario and/or only select the scenarios that best represented their system's capabilities for detection, localization and or characterization of the UXO.

The overall performance of the JPG Phase III technology demonstrations for scenarios 1, 2, and 3 (: This is the latest detection data available for UXO sensor systems) is summarized in **Table 1-1**, as categorized by sensor technology (Note: This is the latest detection data available for UXO sensor systems). The table shows that overall performance was better than 50% probability of detection, and many demonstrators found more than 90 percent of the baseline ordnance. However, the false alarm ratio (the number of false alarms per piece of true ordnance) varied from one to eighteen for the seventeen demonstrators. Generically, this equates to an average of six negative responses per true UXO detection.

TABLE 1-1

DEMONSTRATOR ORDNANCE DETECTION BY SENSOR TECHNOLOGY FOR COMBINED SCENARIOS (1,2 AND/OR 3[3])

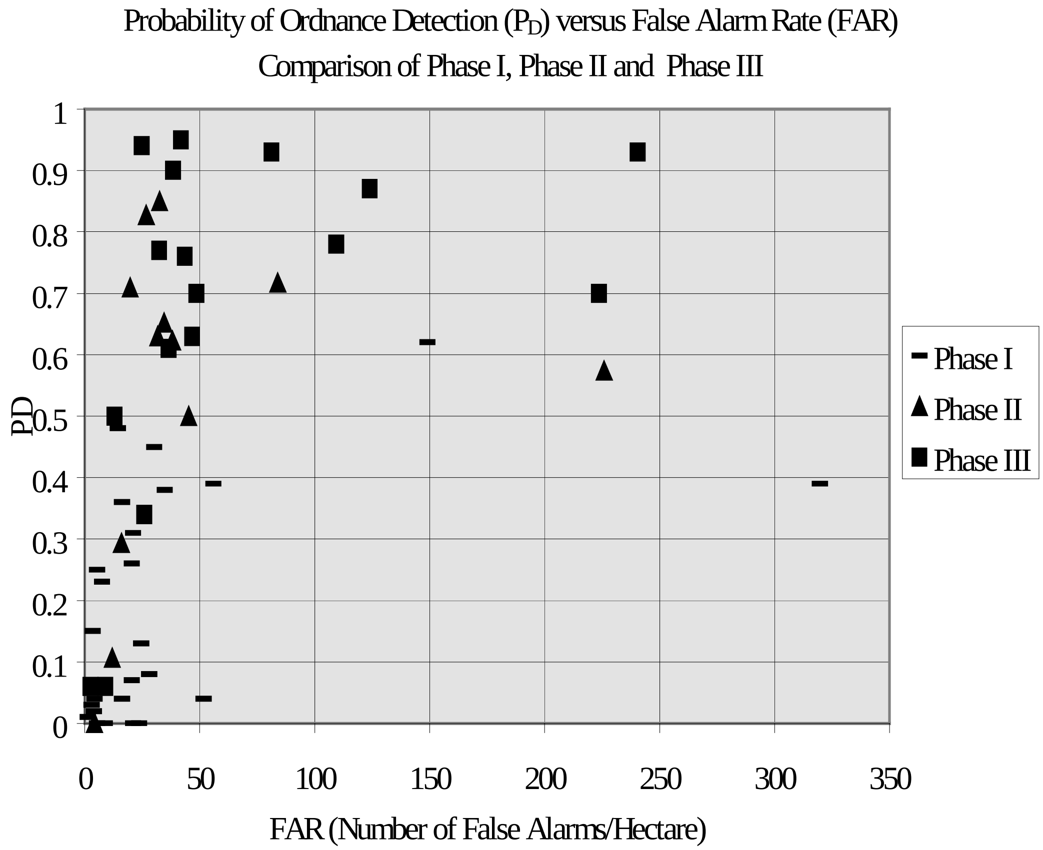
Sensor Type	Demonstrator (Scenario #)	P_D	False Alarm (FA) Rate (#/Hectare)	FA Ratio (#/Ordnance Detected)
Electromagnetic Induction (EM)	CHEMRAD (1,2)	.50	12.90	1.91
	GRI (EM) (1,2,3)	.87	123.89	8.46
	GeoPotential (1,2,3)	.06	9.04	8.54
Gradiometer (Grad)	Foerster (1)	.60	36.46	4.85
Magnetometer (Mag)	Battelle (2)	.12	1.71	1.00
	GRI (Mag) (1,2,3)	.70	223.68	18.82
	Rockwell (1,2)	.34	25.93	5.70
EM & Grad EM & Mag	Geophex (1,2)	.77	32.44	3.11
	ADI (3; Mag only in 1,2)	.78	109.48	8.3
	GRI (Combined) (1,2,3)	.93	240.53	15.23
	Geo-Centers (1,2,3)	.93	81.80	5.18
	Geometrics (2)	.90	38.44	3.00
	NAEVA (1,2)	.94	24.84	1.96
	SCA_ADI (3; Mag only in 1,2)	.63	46.80	4.36
	SCA_Geo-Centers (1,2,3)	.76	43.55	3.36
	SCA_Geometrics (2)	.96	41.86	3.06
Ground Penetrating Radar (GPR) GPR & EM & Grad	ENSCO (1,2)	.70	48.66	5.14
	Average	.68 ± .28	67.18	6.00 ± 4.77

[3] Note: Data is presented for JPG Phase III, Scenario 1,2, and 3 only. These scenarios had representative UXO for demonstrators to search for, localize, and classify. Scenario 4 was not a detection exercise. In scenario 4, targets were marked by the government test coordinators to assess the capability of demonstrated systems to *classify marked targets.*

Figure 1-1 provides a comparison of the JPG Phase III demonstrated system results to the earlier Phases, specifically providing the probability of ordnance detection versus the false alarm rate (in false alarms per hectare). Desired performance is in the upper-left hand corner of the graph (that is, high probability of ordnance detection with low false alarms). At every successive phase, the general trend is that detection rates are improving with no target discrimination capability demonstrated and an increase in false alarm rates. All the previous JPG Phase I, II and II reports are available on the USAEC website: www.aec.army.mil.

To better capture data relating to the true nature of the UXO detection, FAR, and the risk equation, the scope of the JPG Phase IV technology demonstration was narrowed to evaluate the state-of-the-art in UXO discrimination *methodologies.* The data collected in JPG IV will hopefully assist DOD, other Federal government Departments and Agencies, and our private industry partners in better assessing and determining the course of the UXO technology objectives as they relate to real world implementations (although admittedly, the reported data herein is only for one geophysically unique site).

Figure 1-1


Probability of Ordnance Detection (P_D) versus False Alarm Rate (FAR)
Comparison of Phase I, Phase II and Phase III
PD
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
200
250
300
350
FAR (Number of False Alarms/Hectare)
Phase I
Phase II
Phase III

2.0 TECHNOLOGY DEMONSTRATION METHODOLOGY

Results of the technology demonstrations under JPG Phases I, II, and III and findings of DOD principal investigators indicate that state-of-the-art UXO detection technology, such as magnetometer and active electromagnetic induction systems, have high false alarm rates because current sensor technologies are not able to distinguish UXO from man-made clutter. The purpose of JPG Phase IV is to identify technologies capable of determining whether or not a target is UXO. Because a significant portion of remediation funding is spent on excavating targets that are not UXO, USAEC mandated that the JPG Phase IV demonstration seek technologies that have discrimination capabilities. The term "discrimination" refers to technology or techniques that can be used to determine whether an anomaly, previously detected and localized by passive or active methods, is UXO.

2.1 JPG Phase IV Program Objective and Goals

For JPG IV, the objective for an effective discrimination capability was assigned as follows:

- 95% effective discrimination of UXO targets that range in size from 20 mm projectiles to 155mm projectiles, and
- 75% effective discrimination of comparable-sized non-UXO (clutter) targets,

Such discrimination effectiveness levels would reduce the number of unnecessary excavations at remediation sites. Based on knowledge learned in the earlier phases, the goals set for Phase IV of the JPG Technology Demonstrations were to:

- ♦ Demonstrate the capabilities of technology to discriminate between ordnance and non-ordnance.
- ♦ Establish discrimination baselines of sensors and systems.
- ♦ Make raw sensor data available to the public for future analysis efforts.
- ♦ Focus future RDT&E efforts.
- ♦ Establish state-of-the-art for predicting the "class" of ordnance.
- ♦ Address issues raised from prior JPG phases.

2.2 SITE LOCATION AND DESCRIPTION

JPG is located about 5 miles north of Madison, Indiana, in Jefferson, Ripley, and Jennings counties. The facility covers about 22,365 hectares (55,265 acres) and includes former firing lines and impact areas. The base was used for over 50 years, until 1995, to test ordnance and related systems. The Indiana Air National Guard still uses the facility. The Phase IV demonstrations were conducted on a 16-hectare area in the northwest quarter of Section 36, Township 6 North, Range 10 East, the same area used for Phase I, II, and III demonstrations of ground systems. The site is located adjacent to access roads on the East Side of the facility. Detailed information on the site, its geophysical ground truth, preparation, and Quality Assurance is contained in **Appendix B.**

2.3 TECHNICAL APPROACH

The technical approach is similar to the plan for Phase III in that demonstrations were evaluated in terms of realistic UXO range conditions. To this end, NAVEODTECHDIV, in conjunction with Tetra Tech EM Inc. (Tetra Tech) evaluated the existing test area and selected the most realistic target mix, the emplacement of targets on the test site, and the optimal method of emplacement.

The government emplaced a new target set in selected areas of the 16- and 32-hectare areas, including both ordnance and non-ordnance items. Target emplacement depths were determined by considering penetration depths for various types of ordnance[1] in the clayey soils found at JPG (see Appendix B) and by considering depths that were most likely and most practical[2].

A two-part approach within Phase IV was used to fulfill the goals of the program. The first was an enhancement or self-test phase. Demonstrators were encouraged to develop new sensors and procedures and test them on buried targets. All information about the buried targets, including location, depth, type, class, orientation, etc. for 23 ordnance and 46 non-ordnance items was provided to the demonstrators. Six demonstrators were evaluated by a group of government experts and, based upon their proposals, chosen for the self-test phase of testing. The purpose of this phase was to provide the vendors an opportunity to "train" their sensor systems to discriminate ordnance from non-ordnance items

The second part was a blind test. Ten demonstrators, including the original 6 from the self-test phase, performed a discrimination survey of 160 targets (50 ordnance and 110 non-ordnance). During the blind test part, demonstrators were told that a previous survey had uncovered potential burial sites of UXO and the location of each anomaly was marked on the ground. Surface positions were marked with a flag to focus vendor efforts on discrimination rather than detection/location of the targets. In addition, participants were told that more non-

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[1] *Fundamentals of Protective Design for Conventional Weapons*, TM 5-855-1, Headquarters, Department of the Army, November 1986.
[2] *Detection of Unexploded Ordnance*, DDESB TR-76-1, H.H. Henegar, April 1976

ordnance targets were buried than ordnance targets. The assessment of vendors at JPG Phase IV was based solely on their individual capabilities to distinguish between (1) full, intact, inerted, and non-degaussed, hand-emplaced ordnance and (2) man-made, ferrous-content, hand-emplaced debris.

2.4 SITE PREPARATION

Existing ordnance available from the JPG inventory was used to create both the 16- and 32-hectare target areas. Ordnance-related debris, such as partial shell casings, bullet casings, discarded fins, etc., was not part of the layout due to time and budgetary constraints.

Target emplacement locations were initially located using archived information from Tetra Tech and the surveyors. Two-meter radius circles were drawn at each proposed location, thus guaranteeing a minimum four-meter separation in the horizontal plane between centered targets. This was done to eliminate clutter effects from adjacent targets and to ensure a relatively "noise free" local environment. Emplacement locations for the targets were located and flagged by the surveyors using an optical surveying instrument. After the flags were placed and prior to emplacing targets at these locations, a gradiometer was used to check the location for magnetic anomalies within a 2-meter radius of the flag (only at the 16-hectare blind site). Fourteen flags were moved due to anomalous magnetic readings greater than 15 nanoTesla (nT). This was done to ensure that the demonstrator would key on the target signature and not be confused by anomalous magnetic noise.

The emplacement crew used a backhoe to excavate each pre-selected target location to the approximate intended burial depth.

A surveying crew photographed the target either on the surface before it was emplaced or in its' final position. Then the survey crew precisely located each target determining X (easting), Y (northing), and Z (elevation) coordinates. After emplacement, the removed soil was back-filled in and tamped with the backhoe bucket. Quality assurance, after the demonstrations had concluded, showed that this technique is flawed for maintaining elevation (declination) information. Ordnance targets that were placed in the ground in orientations other than vertical or horizontal would collapse to the horizontal position, changing orientation by as much as 35 degrees. Quality assurance is discussed in the Appendix B.

2.5 SITE LAYOUT

"Real world range clutter" has never truly been characterized, as the clutter target set is conceivably immense. Further, "clutter" was not available in quantities or sizes necessary for the spectrum of ordnance targets buried. To make the test demonstration challenging and repeatable; non-ordnance targets were fabricated that represented the weight, volume, material, and/or aspect ratio characteristics to the UXO targets employed in the JPG IV demonstration.

UXO items ranged in size from 20mm rounds to 155mm projectiles. Results from previous phases showed that small to medium sized ordnance targets were the hardest to detect

and classify. Non-ordnance targets consisted of scrap metal cut to "ordnance type" weights (UXO system weight includes explosive filler). Similar, as well as dissimilar, aspect ratios of non-ordnance scrap to ordnance items were also buried. Metallic content of the scrap was limited to iron and steel. Scrap metal weights ranged from 0.15 lbs. to 142.5 lbs., representing weights less than a 20mm round to roughly 40% heavier than a 155mm projectile. .   Most samples of ordnance and non-ordnance buried at the 16-hectare site were replicated at the 32-hectare site.

Tetra Tech provided demonstrators with site and target information related to the ordnance targets and non-ordnance targets emplaced at both the blind test and self-test sites. Page seven of the demonstrator work plan (DWP) for the 16-hectare site states that:

> "The Phase IV demonstration design is based on the premise that about 160 targets of interest have been located in a previous electromagnetic search at the 16-hectare site. Most of the targets are non-ordnance (non-UXO). The horizontal position of the targets will be provided to the demonstrators, and the targets will be marked in the field. Demonstrators will be required to interrogate the targets as to their nature (UXO or non-UXO) and provide any additional information of suspected UXO targets that would be useful to excavators. In addition, demonstrators are to prioritize their interrogated targets list such that the first target listed is most likely UXO and the last target listed is most likely non-UXO".

Plastic flags were placed over each target; therefore, removing the requirement to navigate back to the source of an anomalous signal. This was done to remove the navigation burden from the demonstrator so that time spent in the field was focused on the JPG Phase IV objectives and goals. However, discrimination technologies, and of course detection technologies, in UXO clearance operations should require the capability to relocate unmarked targets for "interrogation," given the UTM coordinates of the target.

2.5.1 Self-Test Area (32-Hectares)

The purpose of this phase was to provide the vendors an opportunity to "train" their sensor systems to discriminate ordnance from non-ordnance items. The government provided demonstrators access to a self test site in the northeast corner of the 32-hectare (80-acre) test area for self-testing prior to demonstrating on the 16-hectare blind test site. A total of 71 targets were marked and identified in the self test area as follows: 23 inert ordnance targets ranging in sized from 20mm to 155mm rounds, 46 non-ordnance targets, and 2 empty holes. All information about the buried targets, including location, depth, type, class, orientation, etc. was provided to the demonstrators.

2.5.2 Blind Test Area (16-Hectares

The 16-hectare area (40 acres) was used for all JPG Phase IV "blind test" demonstrations where a total of 160 targets were emplaced in four test areas. The four test areas were developed to provide:

- Access for multiple demonstrations. Four areas would allow two demonstrators access to the site during the same timeframe without interfering with each other.
- Areas that were not utilized in previous JPG Phases.
- Terrain with enough topological variety that any sensor system heavily dependent upon ground conditions (topography, vegetation, and access) would hopefully show a difference in performance and thereby improve the objectivity of the demonstration.

Of the 160 targets, 50 targets consisted of inert ordnance items and 110 targets consisted of unique non-ordnance items. A listing of all these targets are provided in Appendix B. Demonstrators were informed that a previous survey had uncovered potential burial sites of UXO and the location of each anomaly was marked on the ground. Surface positions were marked with a flag to focus vendor efforts on discrimination rather than detection/location of the targets. In addition, participants were told that more non-ordnance targets were buried than ordnance targets.

Unlike JPG III, where there were different UXO scenarios, the four areas that were utilized in JPG IV were all similar. Representative samples across the spectrum of ordnance types were buried in each of the four areas while non-ordnance to ordnance ratio of roughly 2:1 was maintained. As such, in the event that demonstrators collected data over some, but not all of the areas, ordnance to non-ordnance ratios would not be an issue. Also, each area would have a preponderance of small, medium, and large targets. Further, the four areas did have topological variety to assess the dependence of a sensor system on site conditions, using similar target sets.

2.6 DEMONSTRATOR SELECTION PROCESS

Candidates for JPG Phase IV technology demonstrations were solicited through *Commerce Business Daily* **(CBD August 6, 1997)**. Sixty (60) vendors requested and were then sent information packages that included the program background, JPG Phase I, II and III summaries, Phase IV goals and requirements, and the criteria for selection.

Criteria for the proposal evaluation included the following:

- Technical merit
- Past performance
- Practicality of use of the their technology at JPG
- Value of their involvement to the government
- Cost of their involvement

Twenty proposals received JPG Phase IV consideration and ten were rejected for being outside the planned scope. During the proposal evaluations, the Government selection panel selected and funded:

- Six (6) vendors for participation in JPG Phase IV data collection in both the self-test area and the blind test area. Vendors were reimbursed for testing and tuning their

systems in the spring and summer of 1998 in the self-test area. After this "self test" opportunity, the vendors returned in the late summer and fall of 1998 to perform a limited "blind test" on the 16-hectare site.

- Four (4) additional vendors were provided funding to participate in the collection of discrimination data at the blind test area. The vendors performed a limited "blind test" on the 16-hectare site in the late summer and fall of 1998. These vendors were only allowed access to the representative ordnance and non-ordnance items located in the warehouse.

2.7 DEMONSTRATION PROCEDURES

All selected demonstrators were provided with a demonstration work plan (DWP)[3] that outlined the responsibilities involved in the demonstrations. The DWP provided site background, evaluation criteria, procedures, and data validation information. The Safety, Health, and Emergency Response Plan (SHERP), included in the DWP, served as a guide for day-to-day activities.

Blind test demonstrations were generally scheduled to start on-site by mid-week and conclude by the following Sunday or Monday. The day preceding the start of demonstrations was available for system setup. A Demonstrator Reference Area, a small area outside the controlled site, was available for participants to check their system performance prior to the time limited blind test evaluation. Demonstrators were provided daily local weather forecast, including data collected from an on-site weather station. Discrimination demonstrators and excavation demonstrators had 40 hours to demonstrate their systems capabilities. Hours were logged only while the demonstrators were physically on the grid (blind test area). Discrimination demonstrators were not allowed to dig or remove any objects from the site during the demonstration. Demonstrators were provided with physically flagged baseline target positions. A demonstrators operational time, in hours, was recorded only while the demonstrators were physically on the grid (blind test area).

2.8 DEMONSTRATION DELIVERABLES

Demonstrators were required to provide progress reports every quarter and, within 30 days of demonstration completion, supply three categories of data:

- Administrative data that identified the company and roles of the project team members.
- Equipment data that identified the technologies used in the demonstration.
- Results in the form of a standard data submission that the government used to evaluate demonstrator performance.

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[3] Demonstrator Work Plan (Version 2), Phase IV Controlled Site Advanced Technology Demonstrations U.S. Army Jefferson Proving Ground, Madison, Indiana, July 30, 1998, Tetra Tech EM Inc., Contract # N00174-96-C-0075

The administrative and equipment data was provided to the government in the form of a JPG Phase IV Demonstrator Summary Report. The government provided each demonstrator a data entry disk to ensure standard data submission for evaluation.

3.0 PERFORMANCE EVALUATION METHODOLOGY

The ability to detect subsurface ordnance is critical to the success of UXO site characterization and remediation efforts. During earlier JPG demonstrations, it became evident that there was a problem determining the difference between ordnance and non-ordnance buried targets. Further, as stated in the JPG Phase III Report Chapter 3, "Another issue with detection performance is that a system with a high probability of detection may be of little practical value if it generates an excessive number of target reports that do not correspond to ordnance." .

Demonstrators approached the JPG Phase IV discrimination requirements by using a variety of sensors to sample the environment for anomalous changes caused by the presence of ordnance or materials/geometries of UXO-like items by enhancing their data analysis capabilities. Their sensor sampling strategy was influenced by economics and determined, in part, by their decisions regarding sensor technology, numbers of sensors used, sensor sampling rate, lane spacing, search speed, processing algorithms, and quality assurance with respect to a desired search objective. The evaluation of vendors at JPG Phase IV is based solely on their individual capabilities to distinguish between fully, intact, inerted, hand-emplaced ordnance and man-made, ferrous content, hand-emplaced debris. The evaluation process or methodology was intended for use by site restoration managers or anyone else involved in the UXO cleanup process by: (1) helping them understand the problem, (2) displaying the current state-of-the-art technology and capabilities for discrimination of a detected anomaly, and (3) serving as a baseline for future discrimination exercises.

This report does not include the demonstrator's decision-making processes, or an evaluation of their sensor data and how it was collected. Practical discrimination would involve the ability of a detection system to differentiate a hazardous UXO item or remnant from a non-hazardous one. Phase IV does not attempt to answer this "hazard" question. Instead, Phase IV attempts to answer a subset of that question by burying UXO (perfectly intact and inert) targets, and leaving man-made and natural sources of erroneous signals in the ground. Discrimination for Phase IV is more narrowly defined as "the ability of a demonstrator to detect the difference between inert UXO shapes and man-made ferrous objects."

3.1 DATA FIELDS

All demonstrators were required to fill out a demonstrator data disk containing the following standard data submission fields:

Table 3.1 –1 Demonstrator Data Disk Fields

ENTRY	DESCRIPTION	DEFINITION
1	Demonstrator	Name of the Demonstrator – Government Furnished Information (GFI)
2	Target	Target ID Number (001, 002, 003 etc.) - GFI
3	Northing	Universal Transverse Mercator (UTM) Northing Coordinate using WGS 84 Datum. - GFI
4	Easting	Universal Transverse Mercator (UTM) Easting Coordinate using WGS 84 Datum. - GFI
5	Depth	Distance in meters from the target using the volumetric* center point of the target to the ground surface; a blank entry will be interpreted as "unknown".
6	Type	The kind of target (choices are: *ordnance, non-ordnance, unknown*)
7	Confidence	Demonstrator sureness of correct target typing (choices are: *high, moderate, low, unknown*)
8	Weight	Target weights (choices are: *heavy*>75 kg., *moderate* 10<m>75 kg., *light*<10 kg., *unknown*)
9	Size	An Ordnance targets' major diameter (choices are: *large*>200mm., *medium* 100>m<200mm., *small*<100mm., *unknown*)
10	Azimuth	Bearing of an ordnance items roll axis (tail to nose) in the horizontal plane, ranging from 0 degrees (north) to 180 degrees (south) to 359 degrees. Targets with vertical positions should be entered as "0", if "unknown" as "-99".
11	Declination	Bearing of an ordnance item's roll axis (tail to nose) relative to the ground surface. Values can range from -90 degrees, or nose pointed directly up, to 90 degrees, or nose pointed directly down. A value of 0 degrees lies in the horizontal plane. If declination is "unknown" it should be entered as "-99".
12	Class	Target Class (choices are: *mortar* or *projectile (e.g. 60mm mortar, 76mm HEAT)*
13	Comments	Any notes or observations that the demonstrator wants to make.

* Surveyed depth was from the ground surface to the top middle of the ordnance buried in the horizontal plane. Depth of ordnance buried at 45^{o} was measured from the ground surface to the shallowest tip of the item, nose or tail.

3.1.1 Basis for Discrimination

The basis for discrimination depended upon the ability of the demonstrator to differentiate between ordnance and non-ordnance in the *Type* field. Concurrent with any kind of decision making is the *Confidence* a demonstrator had in making a particular judgment. The main thrust of JPG Phase IV was directed at these two areas. Detection and navigation, which had been major thrust areas of Phases I, II, and III, were not considered pertinent for Phase IV.

3.1.2 Criteria for Discrimination

Given the basis for discrimination, the following terms and procedures are used to describe the performance of individual demonstrators for their ordnance and non-ordnance declarations:

TP	true positive - Baseline ordnance target that is identified by the demonstrator as ordnance
TN	true negative – Baseline non-ordnance target that is identified by the demonstrator as non-ordnance
FP	false positive – Baseline non-ordnance target that is identified by the demonstrator as ordnance
FN	false negative - Baseline ordnance target that is identified by the demonstrator as non-ordnance
O_U	Ordnance declared as "unknown"
N_U	non-ordnance declared as "unknown"
TOB	total ordnance buried
TNOB	total non-ordnance buried
TBT	total baseline target set (TBT = TOB + TNOB)
Unknown	not discovered, identified, determined, or explored

Calculation of **TP Percentage** - $\dfrac{\text{Correct (TP) ordnance declarations by the vendor}}{\text{Total ordnance buried (TOB)}} \times 100$

Calculation of **TN Percentage** - $\dfrac{\text{Correct (TN) non-ordnance declarations by the vendor}}{\text{Total non-ordnance buried (TNOB)}} \times 100$

Calculation of **FP Percentage** – $\dfrac{FP \times 100}{TNOB}$

Calculation of **FN Percentage** - $\dfrac{FN \times 100}{TOB}$

Calculation of **O_U Percentage** - $\dfrac{\text{Ordnance Declared as "Unknown"}}{TOB} \times 100$

Calculation of **N_U Percentage** - $\dfrac{\text{Non-Ordnance Declared as "Unknown"}}{TNOB} \times 100$

A sample calculation is as follows:

Given: Ground Truth consists of 30 ordnance targets and 70 non-ordnance targets (-or- TOB =30, TNOB = 70)

Data for Vendor 1:

- 30 ordnance targets declared as:
  15 ordnance, 10 non-ordnance, 5 unknown (-or- TP=15, FN=10, O_U =5)
- 70 non-ordnance targets declared as:
  35 non-ordnance, 20 ordnance, 15 unknown (-or- TN=35, FP =20, N_U=15)

Table 3.1.2 –1 Sample Calculation: Ground Truth versus Vendor 1 Declarations

	Ground Truth Ordnance	**Ground Truth Non-Ordnance**
Vendor 1 Ordnance Declarations SAMPLE	TRUE POSITIVE PERCENTAGE = (15/30)*100 = 50%	FALSE POSITIVE PERCENTAGE = (20/70)*100) = 28.6%
Vendor 1 Non-Ordnance Declarations SAMPLE	FALSE NEGATIVE PERCENTAGE = (10/30)*100 = 33.3%	TRUE NEGATIVE PERCENTAGE = (35/70)*100 = 50%
Vendor 1 Unknown Declarations SAMPLE	ORDNANCE DECLARED AS UNKNOWN PERCENTAGE = (5/30)*100 = 16.7%	NON-ORDNANCE DECLARED AS UNKNOWN PERCENTAGE = (15/70)*100 = 21.4%

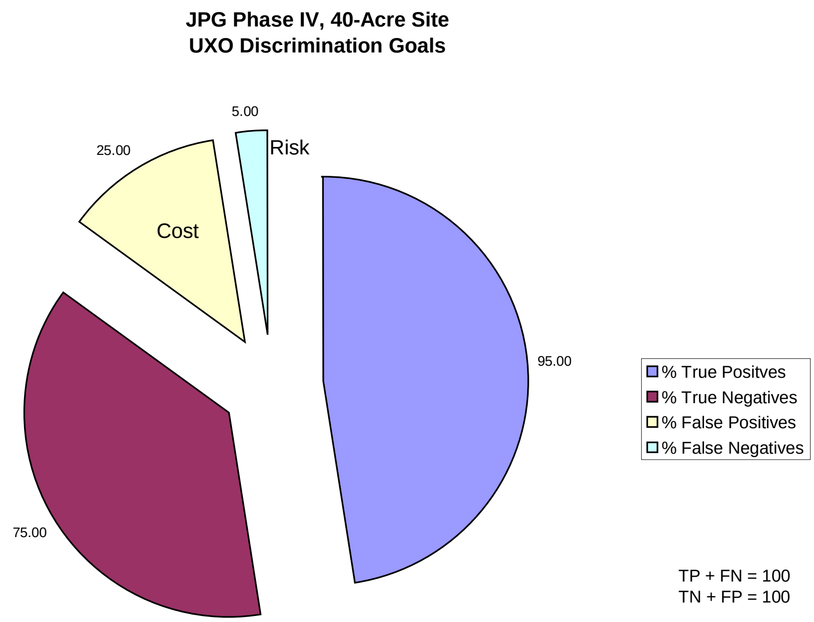
Note: For demonstrators who declare all targets as ordnance or non-ordnance the last row (unknown) of the table does not apply.

3.1.3 Desired Discrimination Capabilities

The discrimination performance metrics for JPG Phase IV was established during the UXO Forum held in 1998. At that time desired goals for the program were to achieve a greater than or equal to 95% true positive rate and a greater than or equal to 75% true negative rate. What does this mean for the site manager or person responsible for cleanup? Graph 3.1.3 presents a picture of this performance metrics. It should be noted that the preceding metric was a subjective goal for the JPG Phase IV demonstration and should not be associated with any site-specific regulatory requirements. Every situation involving UXO involves different levels of acceptable risk. Factors such as end land use (public access), geology factors, government requirements, and funding all contribute to the Cost / Risk equation.

To minimize cost and time, the goal is to dig only ordnance targets (True Positives). Non-ordnance targets (True Negatives) should be left in the ground. What happens with False Positives and False Negatives? False Positives add to the cost of doing business by requiring expenditures of resources on buried items that have no risk associated with them (they are non-ordnance declared as ordnance). On the other hand, False Negatives represent an increase in risk or liability (they are ordnance declared as non-ordnance that is not slated for remediation). The following is a graphical representation. In conclusion, high discrimination ability will maximize the TP & TN, while minimizing the FP & FN.

GRAPH 3.1.3 – 1, Desired UXO Discrimination



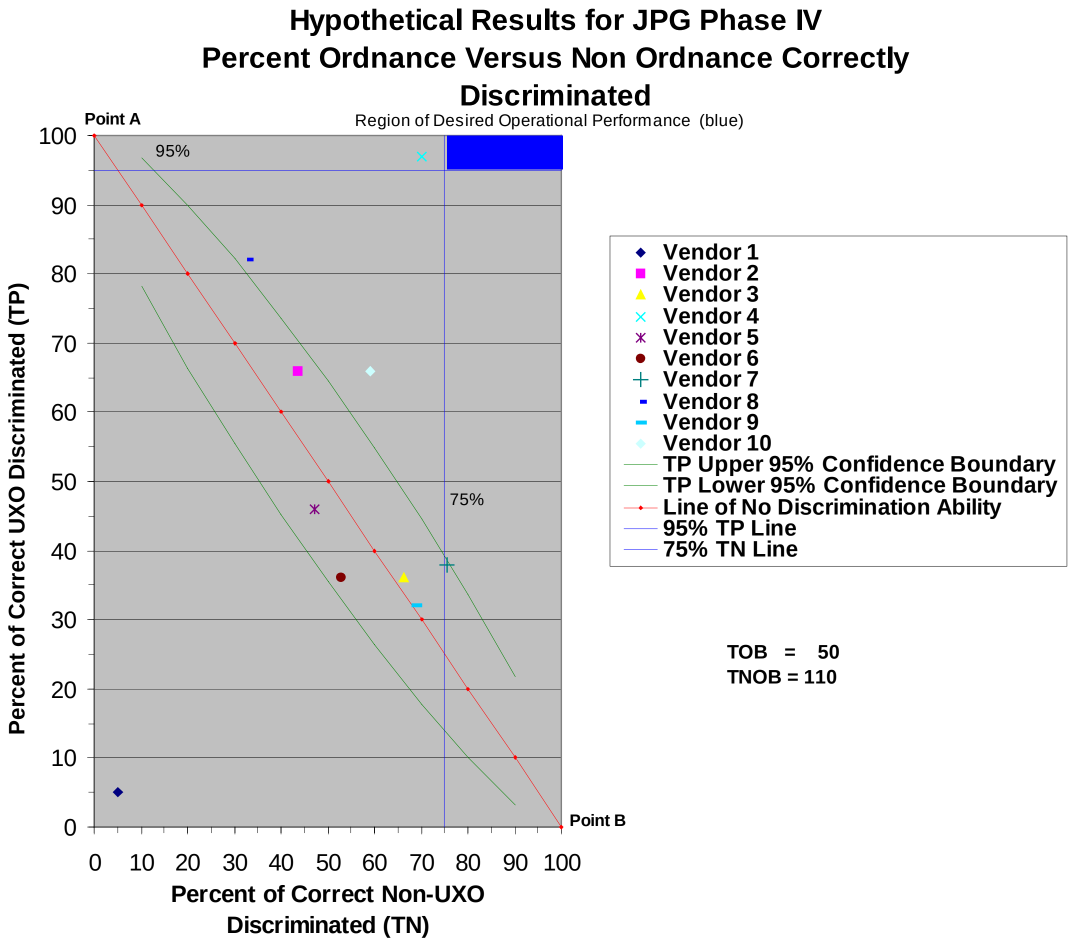
True Positives represent the vendors capability of correctly identifying ordnance from clutter (either man-made or natural) - remediation is required.
True Negatives represent the vendors capability of correctly identifying non-ordnance. No follow on actions are required.
False Positives represent the vendors mis-typing of non-ordnace for ordnance, thus creating an added remediation or cost burden.
False Negatives represent the vendors mis-typing of ordnance for non-ordnance, creating an increased risk to health and safety.

3.2 DISCUSSION OF DISCRIMINATION

Data and graphs, in the rest of this chapter, were designed to aid the reader in assessing demonstrator performance and are hypothetical in nature. View each graph independently to understand the metric being discussed. No correlation should be drawn between vendors shown in this section and actual demonstrators.

It is possible to achieve a 100 percent correct discrimination of ordnance targets as ordnance, true positives, just by declaring all targets as ordnance. Just as it is possible to achieve a 100 percent correct discrimination of non-ordnance, true negatives, by declaring all targets as non-ordnance. This in itself is not a true measure of target discrimination capability. The following graph, 3.2-1, will help clarify discrimination performance:

Graph 3.2 – 1



The red line running diagonally from the top left to the bottom right represents the line of no discrimination ability. The ends of the line show the conditions alluded to above, where the vendor declares all targets to be either ordnance (point A) or non-ordnance (point B). The goal of any discrimination exercise is to get as far away from the red line as possible. The goal of JPG Phase IV (95% TP and 75% TN) is shown as a dark blue rectangle.

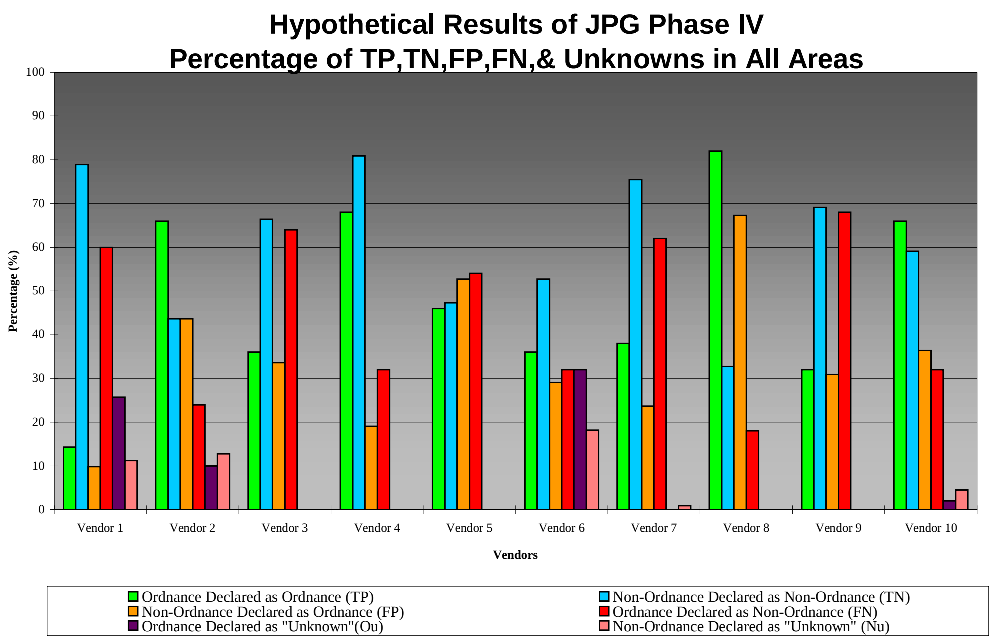
At first glance in these hypothetical results, vendor 4 seems to perform the best. However, vendor 1 has more discrimination capability. Vendor 1 has serious mistyping errors, calling UXO non-ordnance and vice versa, but excellent knowledge of “differences” and therefore the ability to discriminate. The green lines represent the upper and lower 95% confidence level brackets. Performance outside the green lines means that there is a greater than 95% chance that the vendor could discriminate between UXO and non-UXO, that performance was just not a matter of luck. The worst performers are vendors 3 and 9. Their discrimination capability is no better than chance.

3.3 EVALUATION OF DEMONSTRATOR DATA

Various graphs were generated for this demonstration project showing data from different perspectives. It is important to evaluate these graphs as a whole body of work rather than picking the statistic that is most appealing and arriving at a judgment. One must keep in mind that while discrimination is important, it is not the only factor involved in a successful cleanup. For example, if sensors don't detect the target to begin with then there is nothing to discriminate, or, if the "process" is flawed a confident decision can not be made.

Collectively, the two example graphs (3.3-1 & 3.3-2) show the relationship between the ability to declare UXO and non-UXO and the confidence in making those decisions. In Graph 3.3-1, TP and TN should be maximized and FP and FN should be minimized. In Graph 3.3-2, high confidence levels substantiate the discrimination capability of a vendor. For example, vendor 4 shows second-to-the-best TP and the best TN in graph 3.3-1while the confidence graph 3.3-2 tends to support their decision-making ability**.**

Graph 3.3 – 1

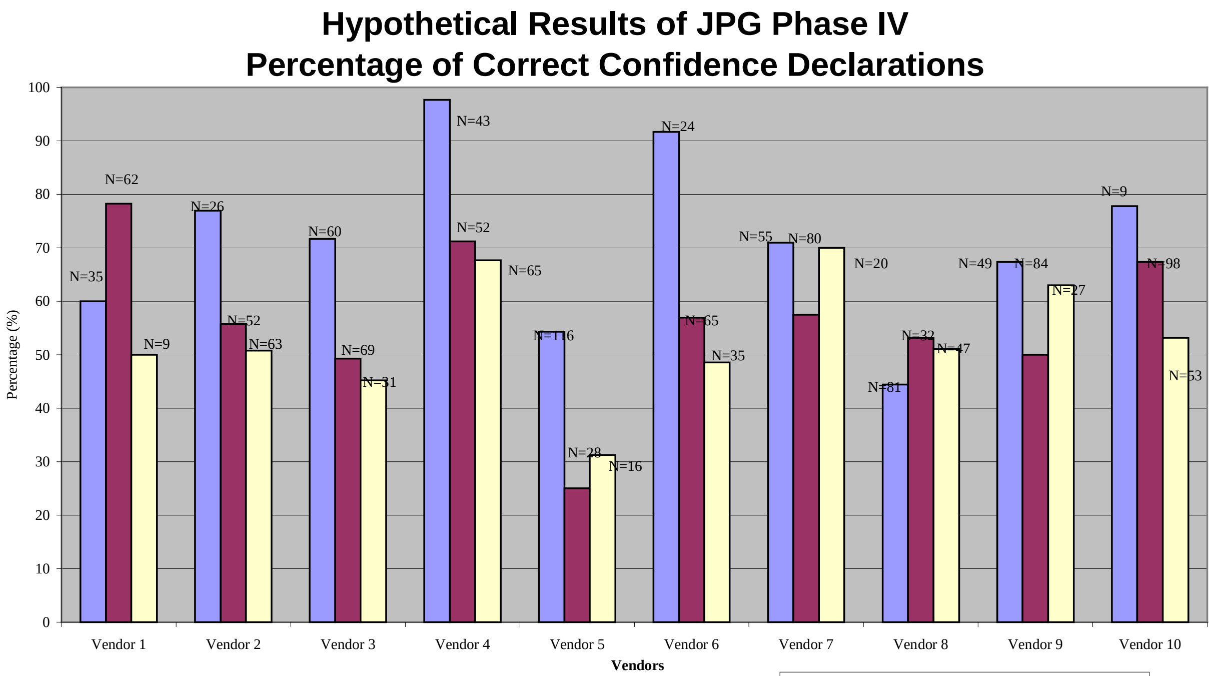


Ordnance declared as unknown (O_u) and Non-ordnance declared as unknown (N_u) is presented as percentages of targets that could not be identified. Declarations of unknown should not be treated in a positive or negative way. The demonstrators' decision-making ability, intentions, or motivations are unknown and therefore cannot be analyzed.

Although vendor 8 shows the best TP, the confidence chart indicates there may be a problem with their decision making (because the confidence in their declarations were predominantly moderate to low), over and above their high FP rate. Vendors 5, 7, and 9 show

questionable decision capabilities in graph 3.3-2 because their percentages of correct "low" confidences were greater than their "moderate" confidences.

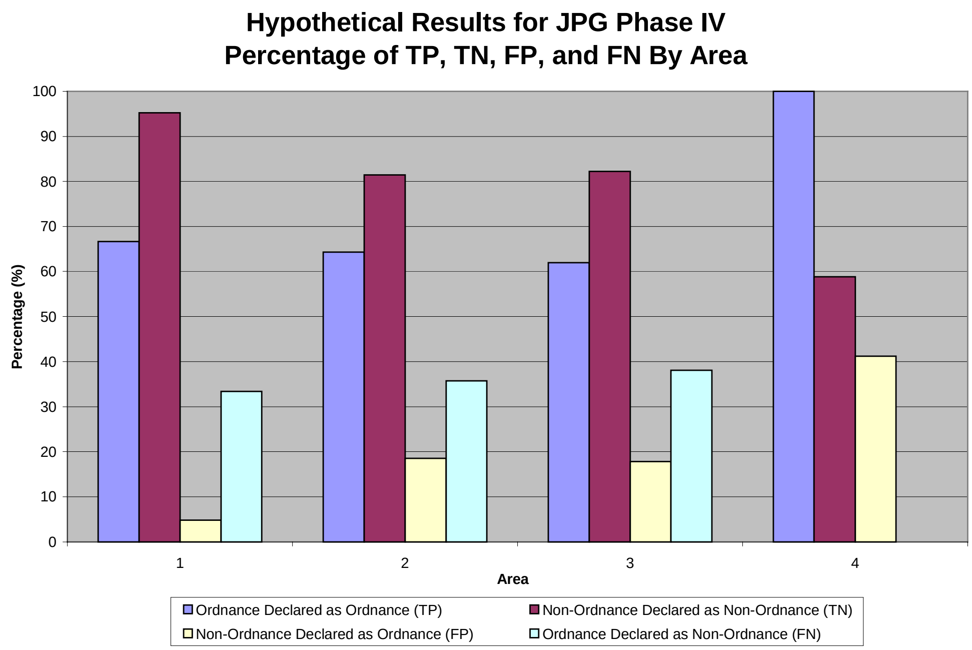
Graph 3.3 – 2



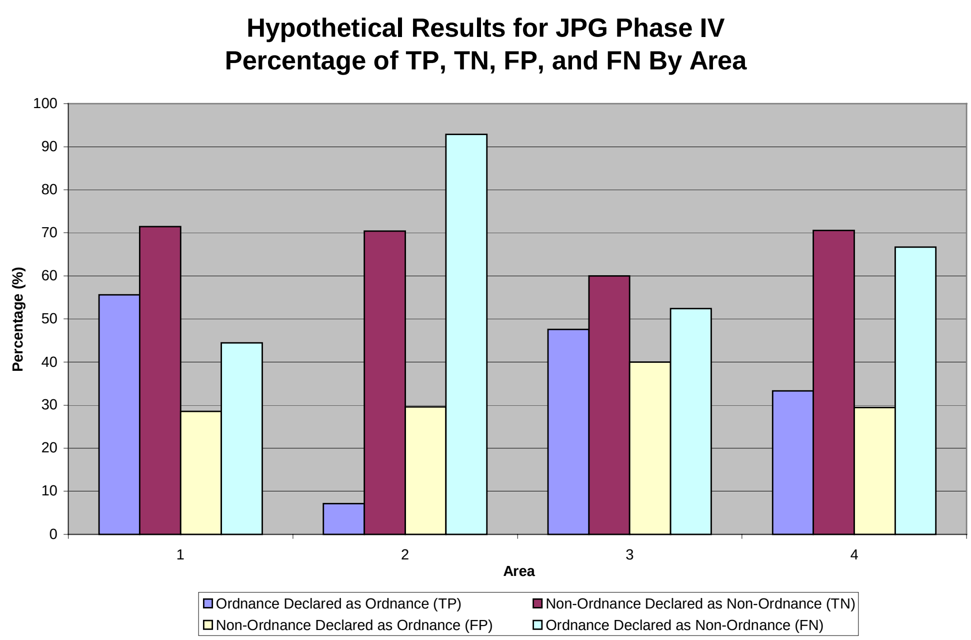
N = Total Number of Demonstrator Declarations

Note: (Number of Particular Confidence Level Declarations, where Correct Ordnance or Non-Ordnance Declarations were made / Total Number of Particular Confidence Level Declarations made) x 100

Graph 3.3 – 3, Vendor ABC



Graph 3.3 – 4, Vendor XYZ

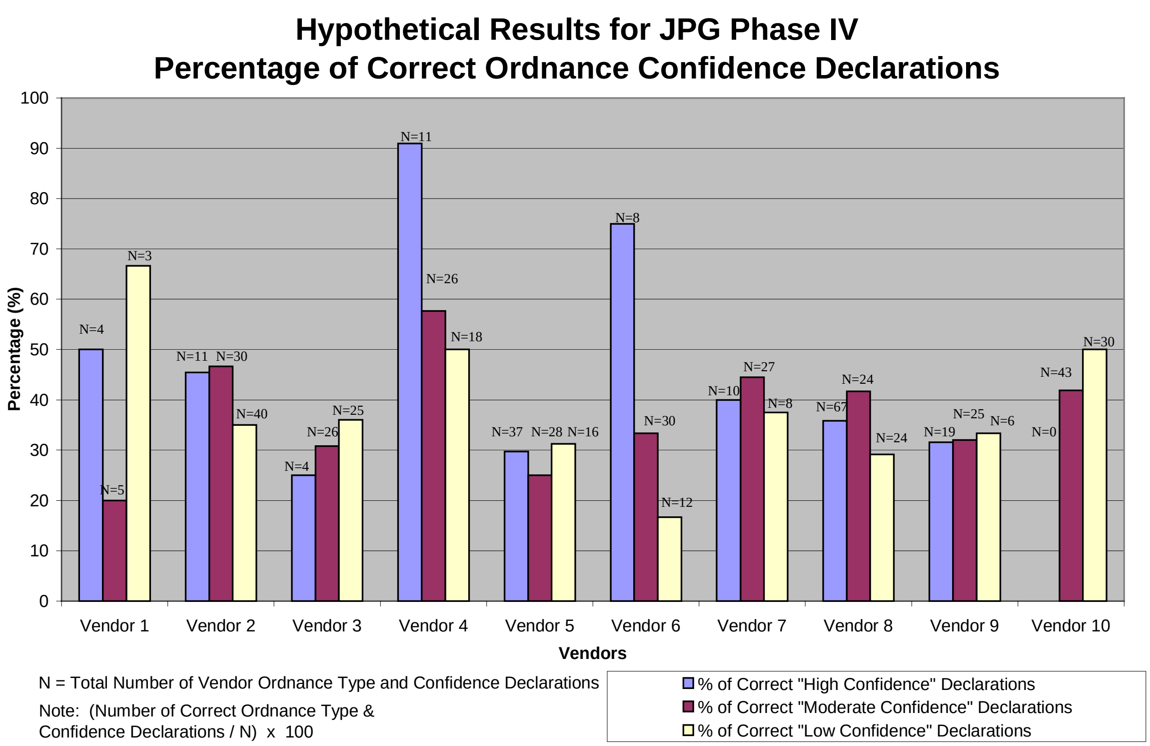


Comparison of a given vendor's performance by area can be significant. Large fluctuations between a vendor's performance could be due to the selection of ordnance, small sample population set, burial depth, or ground geology. Graph 3.3-3 shows vendor ABC data

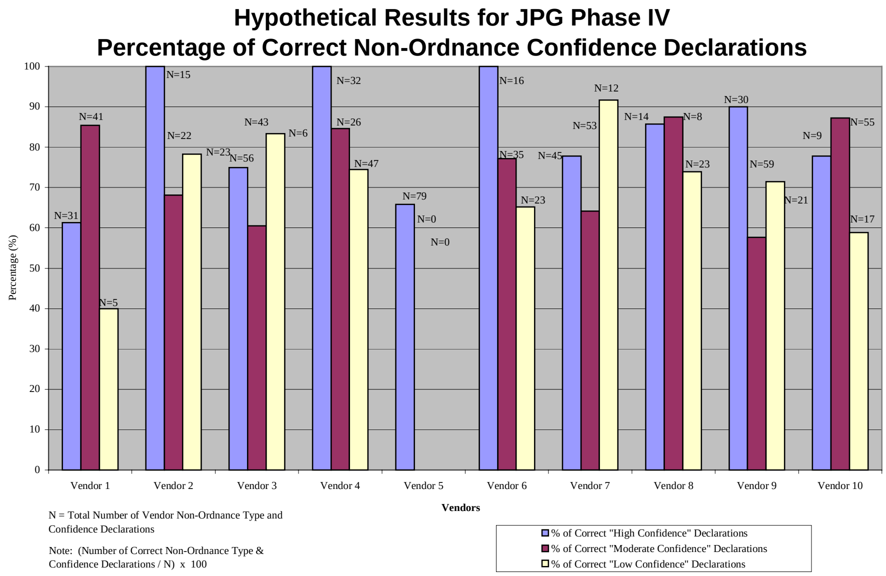
that is fairly consistent from area to area, only area 4 is significantly different. This variation may be due to phenomenology effects. Phenomenology, as used here, may be defined as one or more of the following effects: (1) geology, (2) topography, (3) vegetation, (4) meteorological effects etc. which can influence sensor performance. On the other hand, Graph 3.3-4 shows vendor XYZ has significant variations in performance from area to area. Area 2 shows a TP of less than 10%, as compared to Area 1's TP of 55%, and a FN greater than 90%. The ability to discriminate non-ordnance targets, TN, seems to be consistent but problems discriminating between ordnance targets and debris exist as evidenced by a high FN rate.

Graph 3.3-5 and graph 3.3-6 shows confidence declarations for ordnance and non-ordnance respectively. Note that vendors #4 and #6 reflect good confidence in their ability to identify ordnance versus non-ordnance.

Graph 3.3 - 5

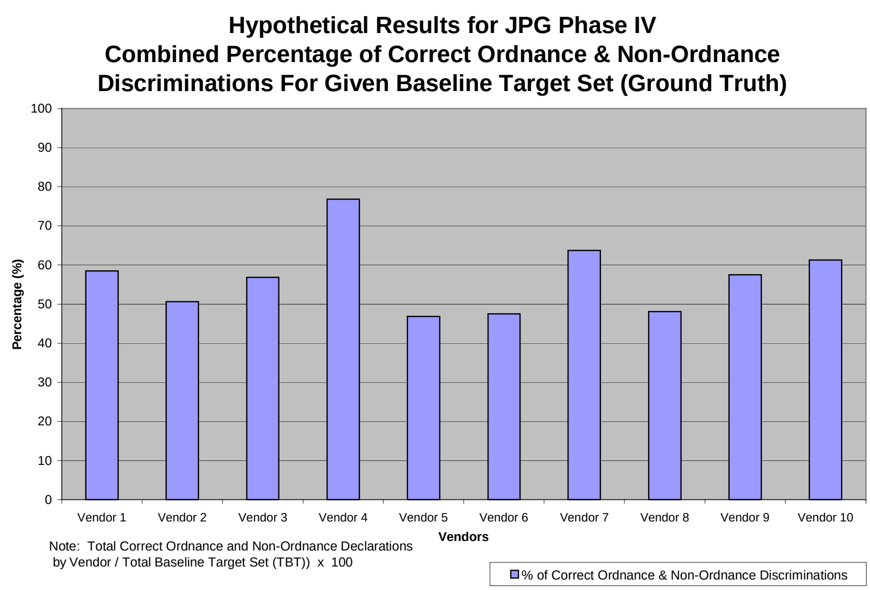


Graph 3.3 - 6



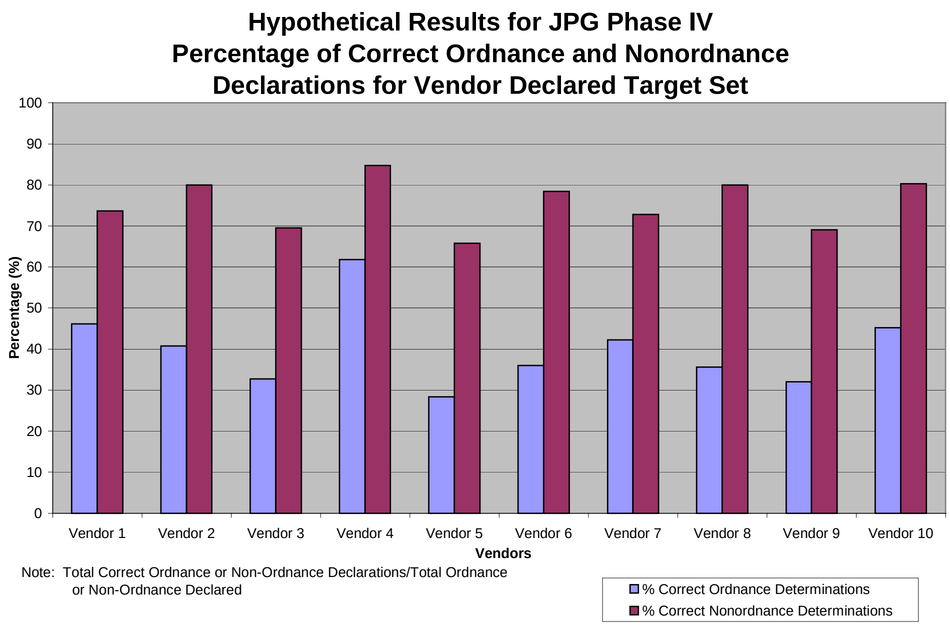
Graph 3.3.7 shows the combined percentages of all correct ordnance and non-ordnance declarations for the baseline target set. Calculation of the percentages are determined by the addition TP + FP at a given confidence level divided by the total baseline target set (TBD = 160) times 100%. It shows an overall ability to discriminate but it is unable to break that down to ordnance and non-ordnance categories. Vendors #4, #7, and #10 showed the best overall discrimination.

Graph 3.3 - 7



Graph 3.3.8 further shows the breakout of correct ordnance declarations from the correct non-ordnance declarations. Calculation of the percentage is determined by the total correct ordnance or non-ordnance declarations divided by the total demonstrator declared ordnance or non-ordnance declarations times 100%. It is important to note that the denominator in this case is not determined by the ground truth data but rather by the demonstrator's own declarations.

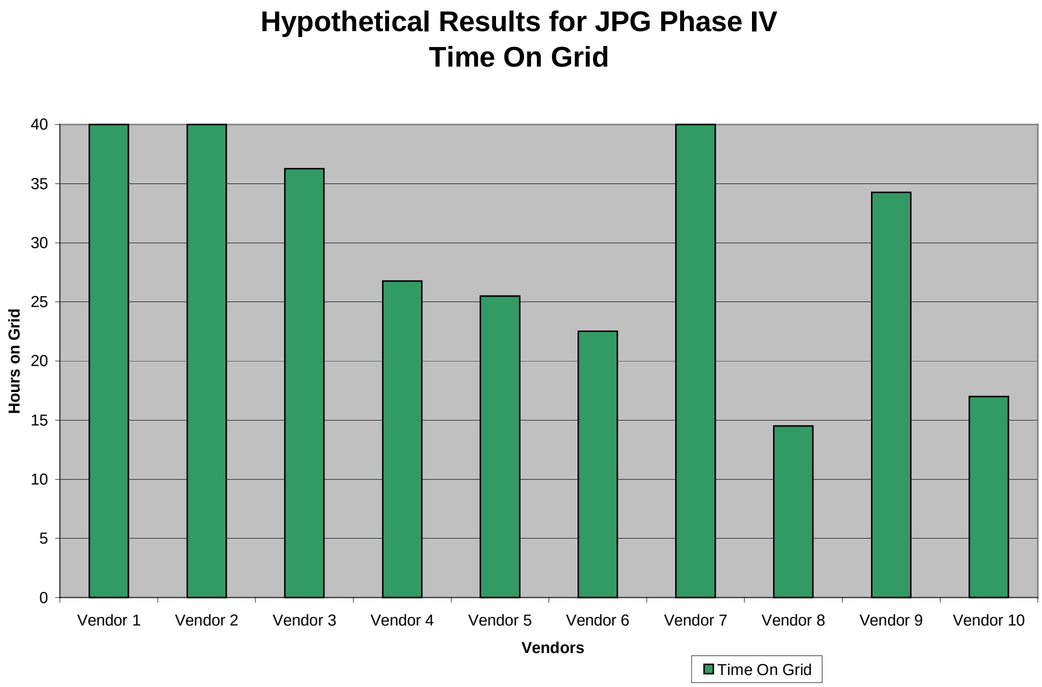
Graph 3.3 - 8



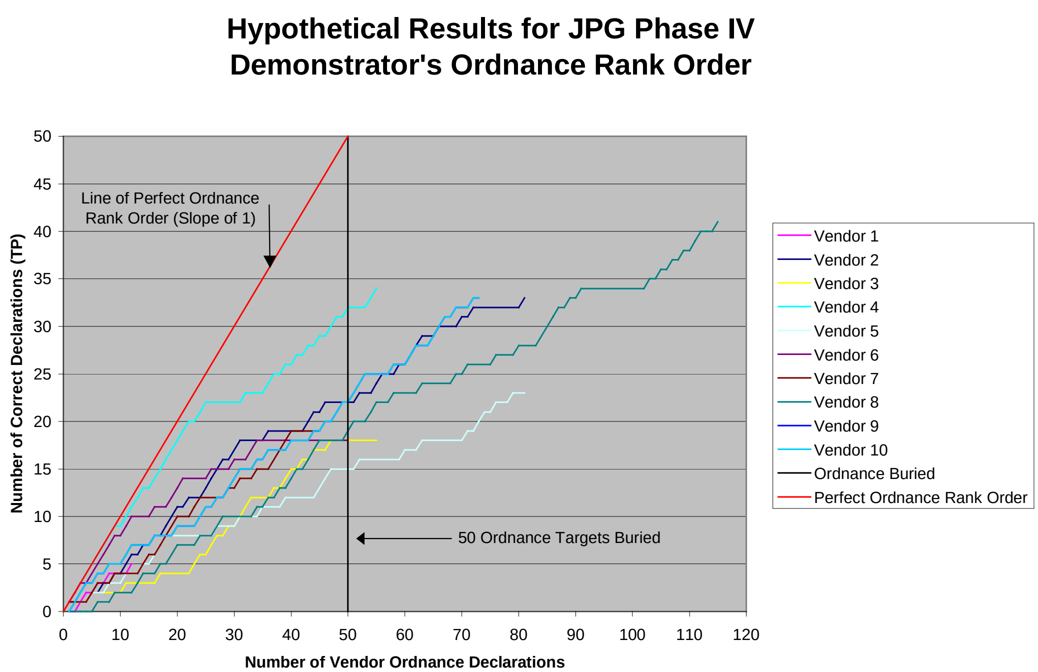
Graph 3.3.9 shows the actual "on grid" time spent by each of the demonstrators. It shows the comparison of data collection times, irrespective of data processing or data analysis. Vendors #8 and #10 might represent more automated or vehicle mounted survey instruments. In addition, time on grid does not necessarily represent vendor system efficiency since vendors may choose to spend additional time on the grid collecting raw data at their discretion to a maximum of 40 hours.

Graph 3.3.10 shows the ordnance-discrimination capability of participating vendors. Vendors were required to rank-order their target declarations from 1 to 160 with 1 being most likely to be ordnance and 160 to most likely be non-ordnance. The graph essentially shows the "rate of correctness" for ordnance discrimination. The end of each line represents the number of ordnance declarations made (x-axis) versus the number of correct declarations, or true positives, up to that point (y-axis). Perfect ranking for the 40-acre site would represent the red line with a slope of "1". Notice that in the example below vendor #4 and vendor #6 start with good ordnance discrimination decisions. Small line segments with a slope of 1 require further investigation to determine if a capability exists to discriminate certain types of ordnance (e.g. similar ordnance signatures may reveal information to the vendor as to the type of ordnance buried).

Graph 3.3 - 9



Graph 3.3 - 10



In Graph 3.3-10, vendor #8 is making too many declarations of ordnance finds, which indicates “playing it safe” by declaring unknown targets as ordnance.

Graph 3.3-11 shows the non-ordnance discrimination capabilities of participating vendors, following the same logic as the previous graph with the exception of the rank-order scheme which starts with target #160.[1]

Graph 3.3 - 11

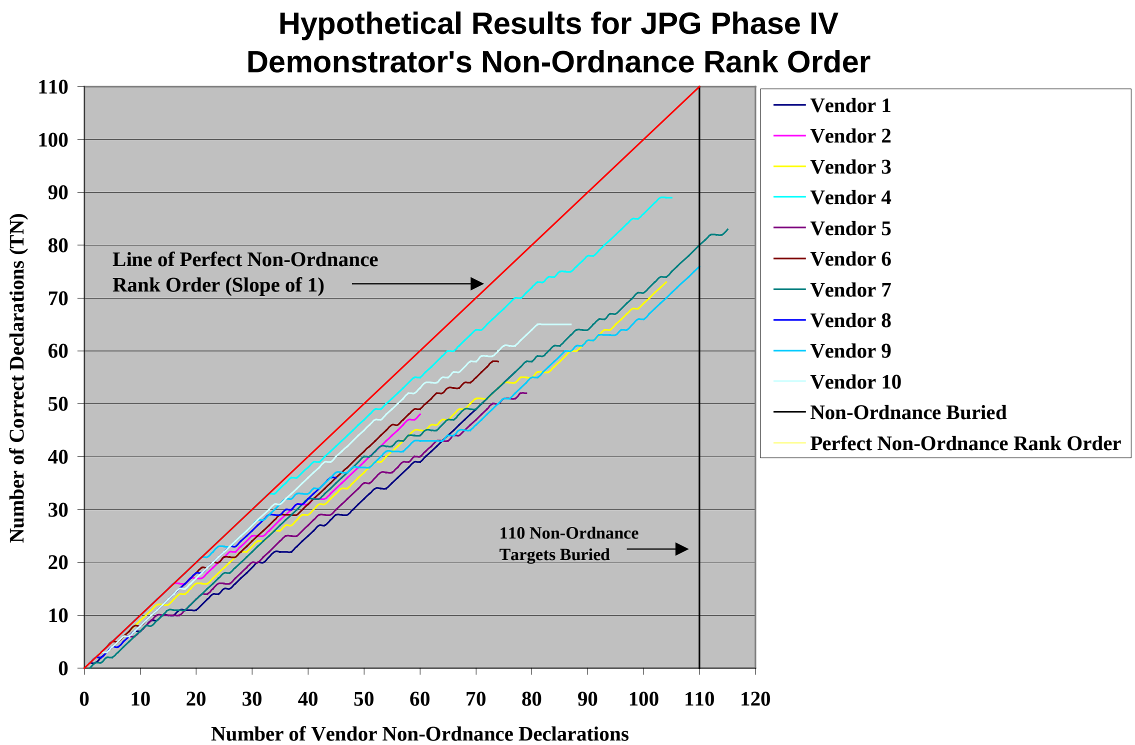


Table 3.3.1 shows the distribution of ordnance items, by UXO type, that were buried and the number of correct discriminations by vendor. A value of "1" in the column represents a correct discrimination (ordnance or non-ordnance). A value of "0" in the column represents a failure to discriminate. This information is important if the desired class of UXO is known ahead of time and a vendor has shown past capability to discriminate these UXO. For example, if 20mm High Explosive Incendiary (HEI) rounds were fired on a range, vendor #4 shows a good ability to discriminate these. If large artillery rounds were fired, then vendor #2 shows a capability to discriminate these. Vendors #8 and #10 show an ability to discriminate 60mm to 4.2" mortars.

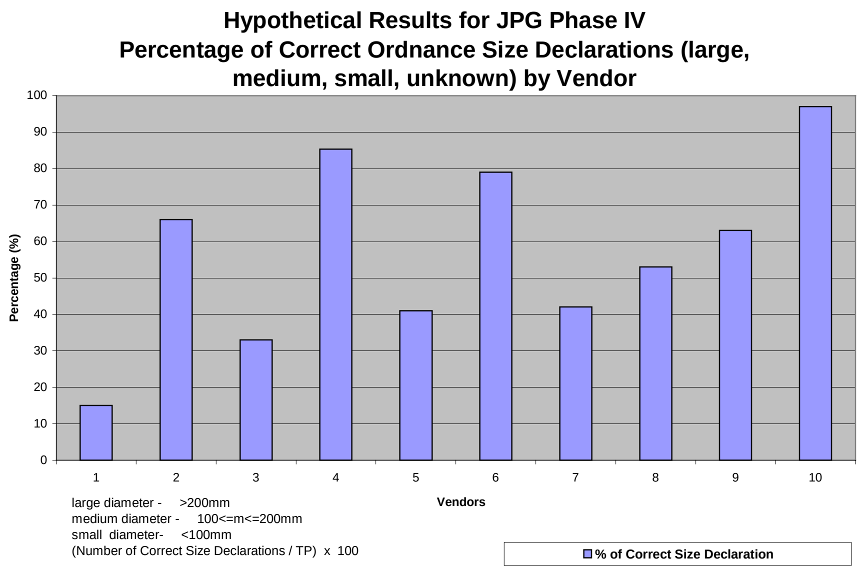
[1] Some demonstrators placed their declared "unknowns" at the end of their rank-order list. These were removed and ranking started with the last non-ordnance declaration.

Table 3.3 – 1, Distribution of Buried Ordnance & Vendor Declarations

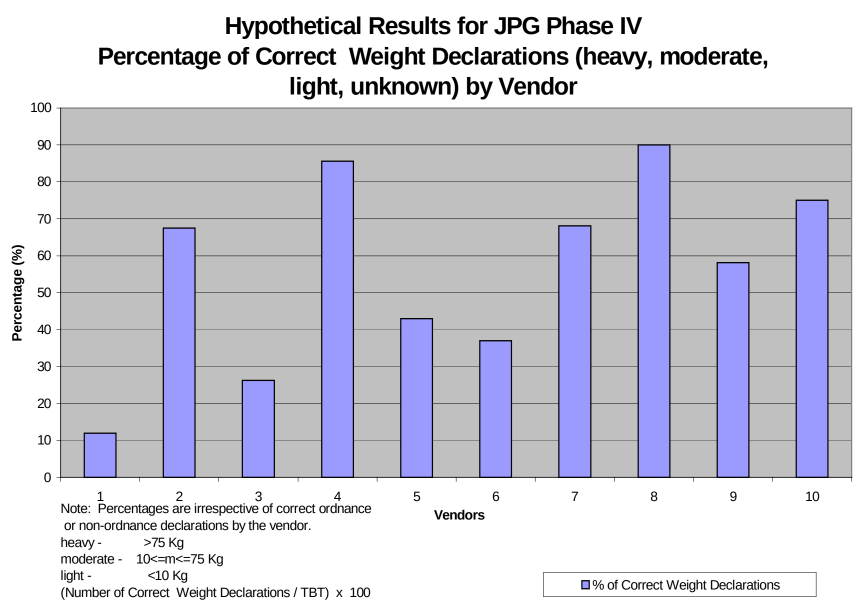
Type of Target	Target #	Vendor 1	Vendor 2	Vendor 3	Vendor 4	Vendor 5	Vendor 6	Vendor 7	Vendor 8	Vendor 9	Vendor 10	TOTAL
20 mm HEI	5	0	1	1	1	1	0	0	0	0	0	**4**
	33	0	1	0	1	0	0	0	1	0	1	**4**
	72	0	0	1	1	0	0	1	0	0	0	**3**
	113	0	0	0	1	0	0	1	1	0	1	**4**
	155	0	0	0	1	1	0	0	1	0	1	**4**
	TOTAL	**0**	**2**	**2**	**5**	**2**	**0**	**2**	**3**	**0**	**3**	
57 mm (HE) wo/fuze, filler	20	0	0	1	0	1	0	0	1	0	1	**4**
	39	0	1	1	1	1	0	1	1	0	1	**7**
	68	0	1	0	0	0	1	0	1	0	1	**4**
	80	0	1	0	1	0	0	0	1	0	0	**3**
	118	1	0	0	0	0	0	0	1	0	1	**3**
	TOTAL	**1**	**3**	**2**	**2**	**2**	**1**	**1**	**5**	**0**	**4**	
60 mm Motar wo/fuze	17	0	0	1	1	1	0	1	1	0	1	**6**
	40	0	1	0	0	1	0	0	1	0	1	**4**
	61	0	1	0	1	0	0	1	1	0	1	**5**
	81	0	1	1	1	1	0	1	1	0	1	**7**
	146	0	0	1	1	1	0	0	0	0	0	**3**
	TOTAL	**0**	**3**	**3**	**4**	**4**	**0**	**3**	**4**	**0**	**4**	
76 mm (HEAT)	21	0	0	1	0	1	1	0	1	0	1	**5**
	46	0	1	0	1	1	1	1	1	0	1	**7**
	67	0	1	0	1	0	0	0	1	0	1	**4**
	88	0	0	0	1	1	0	1	1	0	1	**5**
	123	1	1	0	1	0	0	0	1	0	1	**5**
	TOTAL	**1**	**3**	**1**	**4**	**3**	**2**	**2**	**5**	**0**	**5**	
81 mm Mortar Practice wo/fuze	3	0	1	0	1	1	0	0	1	0	1	**5**
	47	0	1	0	1	1	0	0	1	0	1	**5**
	63	0	1	0	0	0	1	1	1	0	1	**5**
	89	0	0	0	1	0	0	0	1	0	1	**3**
	TOTAL	**0**	**3**	**0**	**3**	**2**	**1**	**1**	**4**	**0**	**4**	
81 mm Mortar (HE) wo/fuze	124	0	0	1	0	0	0	0	0	1	0	**2**
	TOTAL	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	
90 mm (AP) Practice	31	0	1	0	1	0	1	0	1	0	1	**5**
	79	0	1	0	1	0	1	0	1	1	0	**5**
	104	0	1	1	1	0	0	0	1	0	0	**4**
	138	0	0	1	1	1	0	1	1	1	1	**7**
	141	0	0	0	1	1	1	1	1	1	1	**7**
	TOTAL	**0**	**3**	**2**	**5**	**2**	**3**	**2**	**5**	**3**	**3**	
105 mm (APERS) wo/fuze	22	0	1	0	1	1	0	0	1	1	0	**5**
	52	1	1	0	1	1	1	0	1	0	1	**7**
	TOTAL	**1**	**2**	**0**	**2**	**2**	**1**	**0**	**2**	**1**	**1**	
105 mm (HEAT)	98	0	1	1	1	0	0	1	1	1	1	**7**
	137	1	1	1	0	1	0	0	1	1	1	**7**
	148	0	1	0	1	1	1	0	1	1	0	**6**
	TOTAL	**1**	**3**	**2**	**2**	**2**	**1**	**1**	**3**	**3**	**2**	
4.2" Mortar (HE) w/fuze	11	0	1	1	0	1	0	0	1	1	0	**5**
	57	0	0	0	1	0	1	1	1	1	0	**5**
	TOTAL	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**0**	
4.2" Mortar (HE) wo/fuze	99	0	1	0	1	1	1	1	1	0	0	**6**
	TOTAL	**0**	**1**	**0**	**1**	**1**	**1**	**1**	**1**	**0**	**0**	
4.2" Mortar (Illum.) wo/fuze	132	0	0	1	0	0	0	0	1	1	0	**3**
	152	0	1	0	1	1	1	0	1	0	1	**6**
	TOTAL	**0**	**1**	**1**	**1**	**1**	**1**	**0**	**2**	**1**	**1**	
152 mm Practice	27	0	1	0	1	0	1	0	1	0	1	**5**
	51	0	0	0	0	0	1	0	1	1	1	**4**
	92	1	1	1	0	1	0	0	0	0	0	**4**
	105	0	0	0	0	0	0	1	0	1	0	**2**
	114	0	1	1	0	0	0	0	0	0	0	**2**
	TOTAL	**1**	**3**	**2**	**1**	**1**	**2**	**1**	**2**	**2**	**2**	
155 mm (HE) w/lifting lug	56	0	1	0	0	0	1	1	1	1	1	**6**
	90	0	1	1	1	0	1	1	1	0	1	**7**
	117	0	1	0	0	0	0	0	1	0	1	**3**
	TOTAL	**0**	**3**	**1**	**1**	**0**	**2**	**2**	**3**	**1**	**3**	
155 mm (HE) w/fuze	8	0	1	0	1	0	1	1	0	1	1	**6**
	108	0	1	0	1	0	1	1	0	1	0	**5**
	TOTAL	**0**	**2**	**0**	**2**	**0**	**2**	**2**	**0**	**2**	**1**	

The following graphs, 3.3-12 to 3.3-15, show the analysis of data gathered in four other categories. Field categories such as size (3.3-12), weight (3.3-13), depth (3.3-14)[2], and class (3.3-15) from Table 3.1-1:

Graph 3.3 – 12

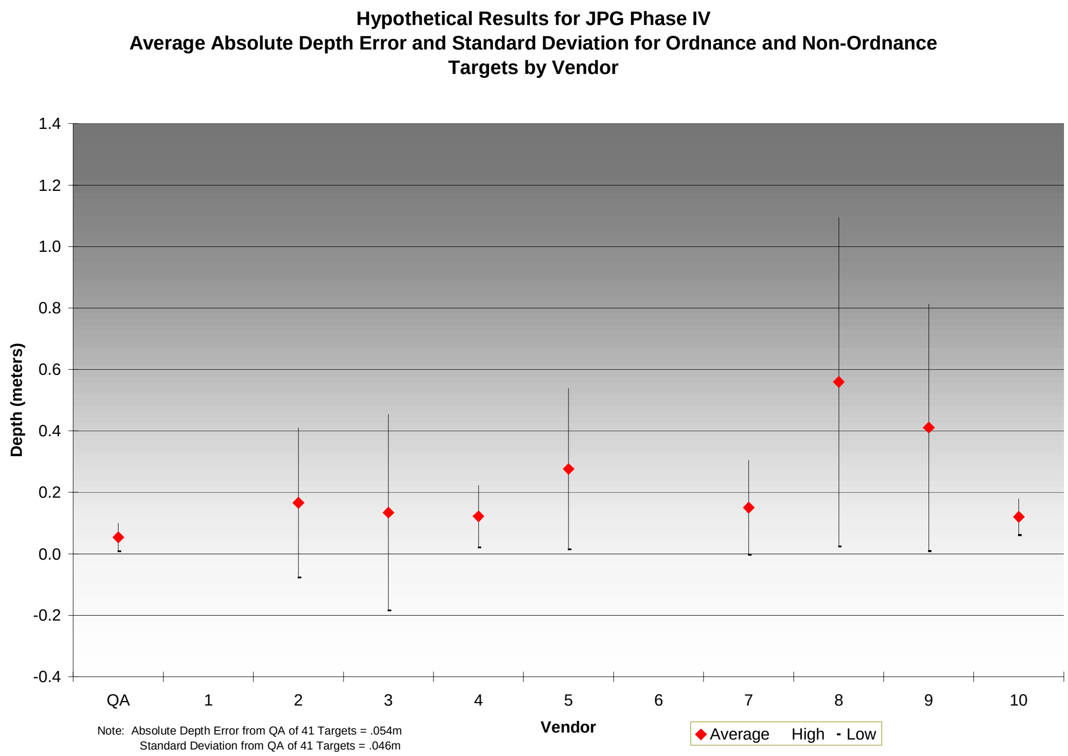


Graph 3.3 - 13

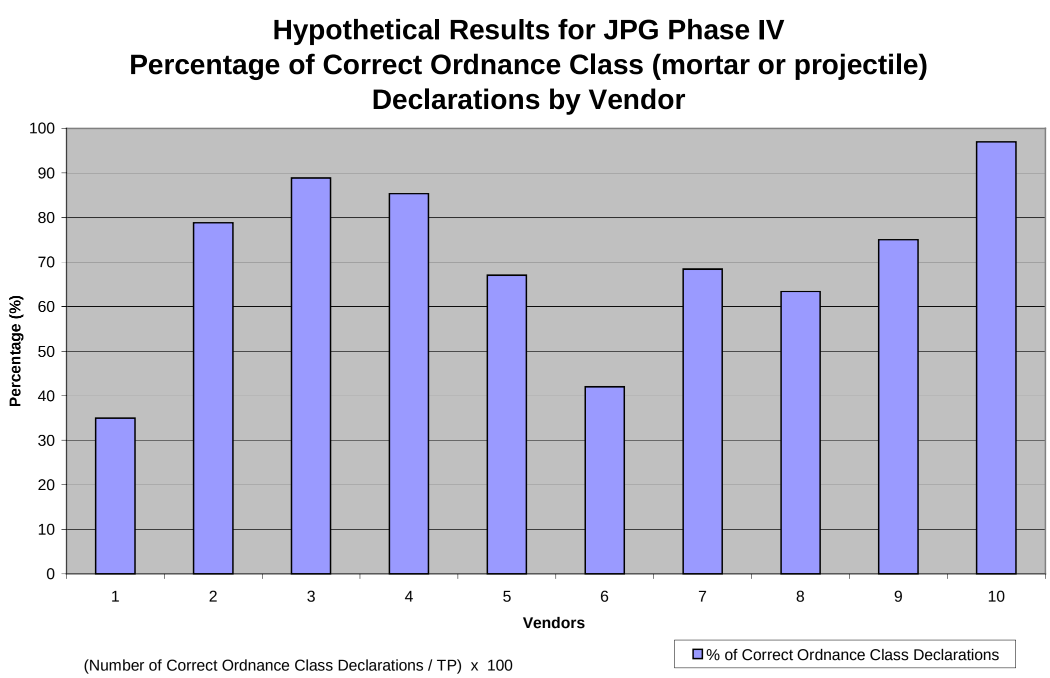


[2] Some depth error is attributable to differences between reporting requirements in the demonstrator data disk (from the anomalies center of mass) and the process used by the surveyors to measure depth (from the closest point of the target to the ground surface)

Graph 3.3 – 14



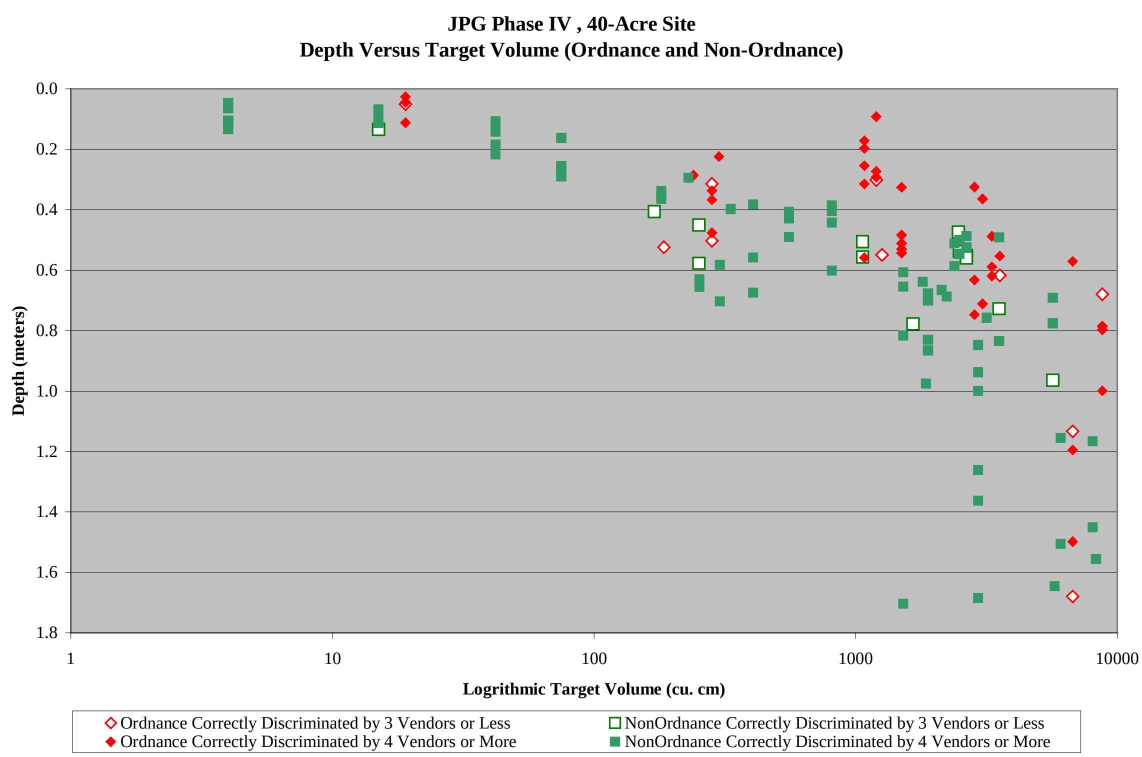
Graph 3.3 - 15



Graph 3.3.14 shows the average and standard deviations of the vendor's data from the surveyor's quality assurance data. Short standard deviation lines and a low average depth error is the desired metric. Quality assurance based upon remediation efforts, by Concept Engineering Group (CEG) and hand removals, were performed during the last week of the demonstration period. This data is shown in the "QA" field of the graph (absolute depth error of .054 meters and standard deviation of .046 meters based upon 41 total targets unearthed). Vendors #1 and #6 either did not provide entries into this field or the entries were incorrect.

Graph 3.3.16 shows the distribution of ordnance and non-ordnance targets as a function of volume (on a logarithmic scale) and burial. Targets that meet the criteria of being easier to discriminate (by a population of 4 vendors or more) are shown as solid markers. Those targets that were more difficult to discriminate have white hollow interiors. Volumes were calculated based on outer dimensions for both ordnance and non-ordnance.

Graph 3.3 - 16



Note: Does not include 25 non-ordnance volumes

3.4 EXCAVATION & QUALITY ASSURANCE

Although not planned for, CEG performed two roles at JPG Phase IV, excavation and quality assurance (QA). The first role was that of a "safe" excavator. CEG uses a supersonic jet of air and a vacuum pump to remove the earth over a UXO target, enabling explosive ordnance

disposal (EOD) personnel to identify the type of ordnance and its associated fuze components. The advantage to this approach is that the ordnance item is positively identified before it is moved or jostled. This technique has advantages for excavation of live UXO since it gently and efficiently removes the overburden soil from above a live round. Bulk excavation on unexploded ordnance is a dangerous procedure. Many approaches have been suggested such as "remote" or "tele-operated" digging and "layered" digging where different techniques are used as one nears an unknown target. Generally, the faster the process of uncovering a UXO the greater the risk to people and equipment.

Data requirements for the CEG demonstration consisted of two fields as follows. First, *transit time*, or the time it takes the equipment to travel from a central staging area to the site and prepare to excavate. Second, *dig time*, or the actual time it takes from the start of excavation to a positive identification of the target.

The second role that CEG provided planners at JPG was that of Quality Assurance (QA). Questions about the accuracy of target locations and burial depths were raised during previous demonstrations. To confirm the accuracy of target locations, surveyors were used to mark targets as they were uncovered by CEG.

3.5 SCHEDULE

Table 3.6-1 provides the actual schedule for both the Self-Test Area and the Blind Test Area. A description of each vendors system can be found in Appendix C. Pictures of each system, as taken during the JPG demo, can be found in Appendix E.

Table 3.5 – 1

PHASE IV TECHNOLOGY DEMONSTRATION SCHEDULE

Date	Vendor	Technology Demonstrated
SELF-TEST SITE		
April 14 - 25, 1998	Sanford, Cohen & Associates	Magnetometer (Mag) and Electromagnetic (EM)
April 27 - May 1, 1998	Applied Physics Laboratory	Pulsed Electromagnetic Induction (PEMI)
May 18 - 30, 1998	NAEVA Geophysics, Inc.	Smartmag and EM
June 1 - 5, 1998	ENSCO, Inc.	Mag, EM, and Ground Penetrating Radar (GPR)
June 22 - 26, 1998	Battelle	GPR
July 13 - 17, 1998	Geophex, Ltd.	Electromagnetic Induction Spectroscopy (EMIS)
July 20 - 24, 1998	Sanford, Cohen, & Associates	Mag and EM
July 27 -31, 1998	NAEVA Geophysics, Inc.	Smartmag and EM
BLIND TEST SITE		
Aug. 17 - 21, 1998	Applied Physics Laboratory	PEMI
Aug. 24 - 28, 1998	NAEVA Geophysics, Inc.	Smartmag and EM
Aug. 31 – Sept. 4, 1998	ENSCO, Inc.	Mag, EM, and GPR
Sept. 14 - 18, 1998	Geophex, Ltd.	EMIS
Sept. 21 - 25, 1998	Battelle	GPR
Sept. 28 – Oct. 2, 1998	Sanford, Cohen & Associates	Mag and EM
October 5 - 9, 1998	Geo-Centers, Inc.	Surface Towed Ordnance Locator System
October 12 - 16, 1998	ADI/Alpha Geoscience Pty. Limited	Mag, EM, and GPR
October 19 - 23, 1998	Geophysical Technology Limited	TM-4 Magnetometer and TM-4ε PEMI
October 26 - 30, 1998	Naval Research Laboratory	Multi-Sensor Towed Ordnance Locator System
November 2 - 6, 1998	Concept Engineering Group	SAFEX Jr., excavation system

4.0 RESULTS

The following tables, graphs, and discussions represent demonstrator performance at JPG Phase IV. Phenomenological investigations from the U.S. Army Waterways Experiment Station (see report in Appendix F) are included to help explain demonstrator performance. Comparative data is presented in graphical form.

4.1 DISCUSSION

Since most demonstrators used more than one instrument to interrogate suspect targets, it is impractical, from the governments' standpoint, to attribute success or failure to a single technology or procedure. The same holds true for discrimination methodology. The ability for the government to impartially determine the most "appropriate" decision making technique is impractical for this performance based test methodology. Table 4.1-1 is a breakdown, by vendor, of the different tools and discrimination techniques brought to the field. With the exception of Battelle, which used GPR and APL, which used PEMI, the eight other vendors used multiple technologies.

Table 4.1 - 1 - Demonstrators' Technologies and Discrimination Techniques

Vendor	Technology	Discrimination Technique*
APL	Pulsed Electromagnetic Induction	Statistical Processing
NAEVA	TF Mag., EM-61, EM-61 3D, Protem 47D	Parameter Matching
ENSCO	Gradiometer, GPR, EM-61HH	Sensor Fusion (matching)
Geophex	GEM-3 Multifrequency EM, TF Mag.	Target Match to Signature Library
Battelle	GPR	Linear Shape using CNR
SC&A	TF Mag., EM-61HH, GPR	Target Signature Comparison
ADI	TF Mag., EM-61HH, GPR	Visual Interpretation of GPR
Geo-Centers	TF Mag., EM-61	Fuzzy Inference
GTL	TF Mag., EM.	Statistical Fit to a Data Set
NRL	TF Mag., EM-61	Physics Based Algorithm
TF Mag. – total field magnetometer, GPR – ground penetrating radar, EM-61HH – EM-61 handheld		
* from demonstrators' proposals		

4.1.1 Phenomenological Studies

Phenomenological studies were performed by the U.S. Army Waterways Experiment Station (WES) and appear in the Appendix F. From this WES report the following general observations are summarized:

(1) Electrical Conductivity (S/m –siemens per meter) - GPR tends to suffer most from variable ground conditions where high ground electrical conductivity leads to high GPR signal attenuation. The major causes of this are high clay content soil and high water content. However, JPG soils are very fine grained quartz silts and sands and attenuation of GPR signals cannot be attributed to high clay content soils in the shallow subsurface where most of the targets were buried. Therefore attenuation from this source must come from high water content. The electrical conductivity of most ordnance is approximately 10^7 S/m while background noise is in the 1 to 17 mS/m range for this site (a low value). The ratio of metallic ordnance to background noise should be approximately 10^9.

(2) Electrical Resistivity (ohm-meter) - WES measured the following resistivity values from 18 August to 27 Oct 1998 in three layers. Layer 1 was from 0.3 to 0.6 meters deep and resistivity measurements ranged from 450-880 ohm-meters. Layer 2 was from 1.0 to 1.6 meters deep and ranged from 80-160 ohm-meters. Layer 3 was 2.6 to 3.5 meters deep and ranged from 25-38 ohm-meters. Analysis of layer 3 data is irrelevant for Phases III and IV since no targets were buried at those depths. Electrical resistivity in layer 1 is too broadband to be applicable to a particular rock or ore type but layer 2 is indicative of topsoil, clay, weathered bedrock, gabbro or graphitic schist[1].

(3) Relative Dielectric Permittivity (ε) - WES measured the dielectric constant (ε) of soils at JPG in the laboratory, with GPR, and a Dicon probe. Assuming a 25% soil moisture content, the permittivity was measured in the lab as 10-13, with GPR at 10.4-10.5, and with the Dicon probe as 19.2.
Average soil water content in grid G7 at 10 cm depth was 13 ± 1% under dry conditions and 33 ± 3% under wet conditions.

(4) Magnetic Susceptibility (k) - Magnetic susceptibility should not vary much for near surface materials. According to WES, no more than 2 or 3 times over distances of tens of meters. Figure 13 of Appendix F shows a 9 fold increase over 60 meters on boundary line sections K4 through K6 of the 40-acre site. This does not affect results from Phase IV since no targets were buried within 75 meters of this region but it has implications for previous phases. Contrasting magnetic susceptibility between metallic ordnance and background material should be on the order of 10^5 or greater according to WES.

[1] Field Geophysics, John Milsom, ISBN 0-471-96634-7

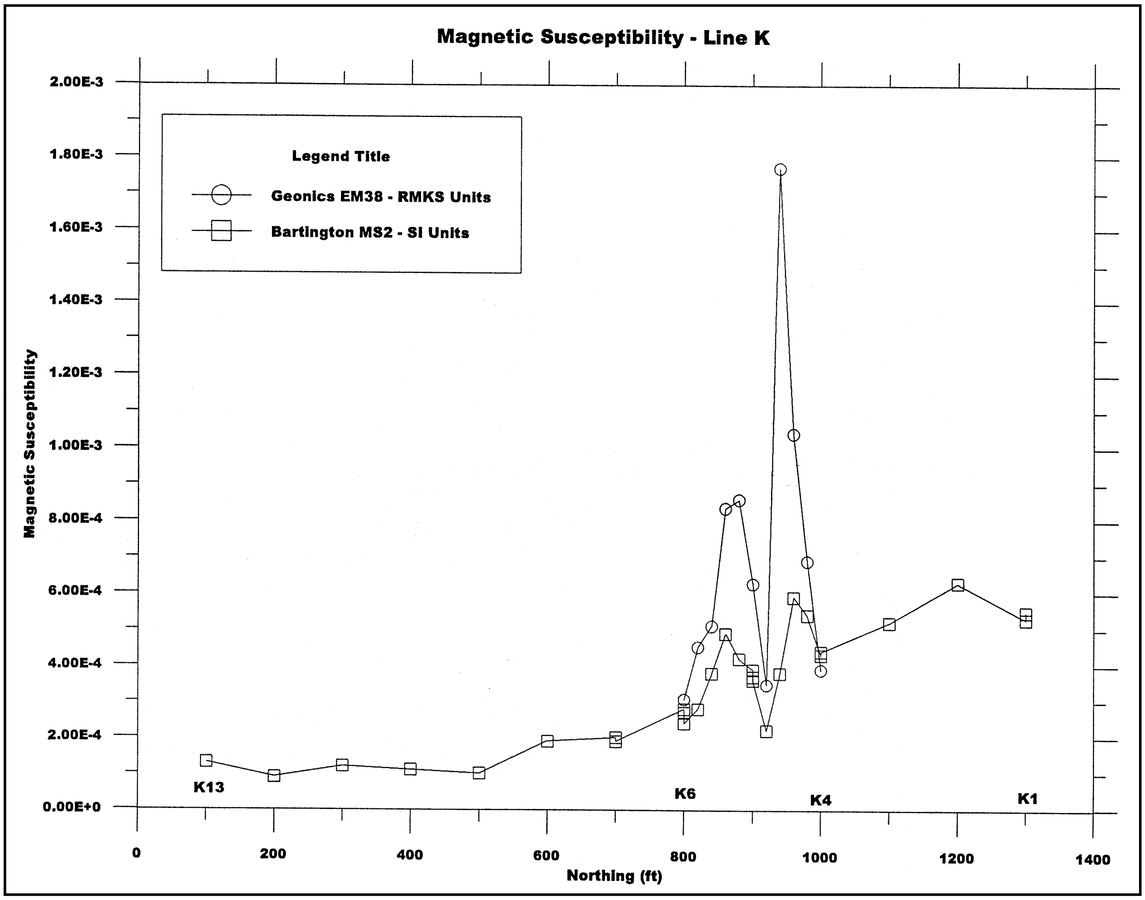


Figure 13. Magnetic susceptibility profiles along grid line K, from K13 to K1

"Large Volume" geologic anomalies in this area (K-M, 4-6) accounted for large negative magnetic exceedences of approximately 130 nT in the south and large positive exceedences of approximately 115 nT in the north (figure 15 of Appendix F).

High water content of soils has been shown to have negative consequences on performance at JPG for GPR. Comparing table 3.6-1 to Figure 14 of Appendix F shows that on September 20 over an inch of precipitation fell on the site. Battelle demonstrated for the next 5 days which could account for some of their less than expected performance. The other two vendors that had to deal with precipitation, Geo-Centers and GTL, did not use GPR.

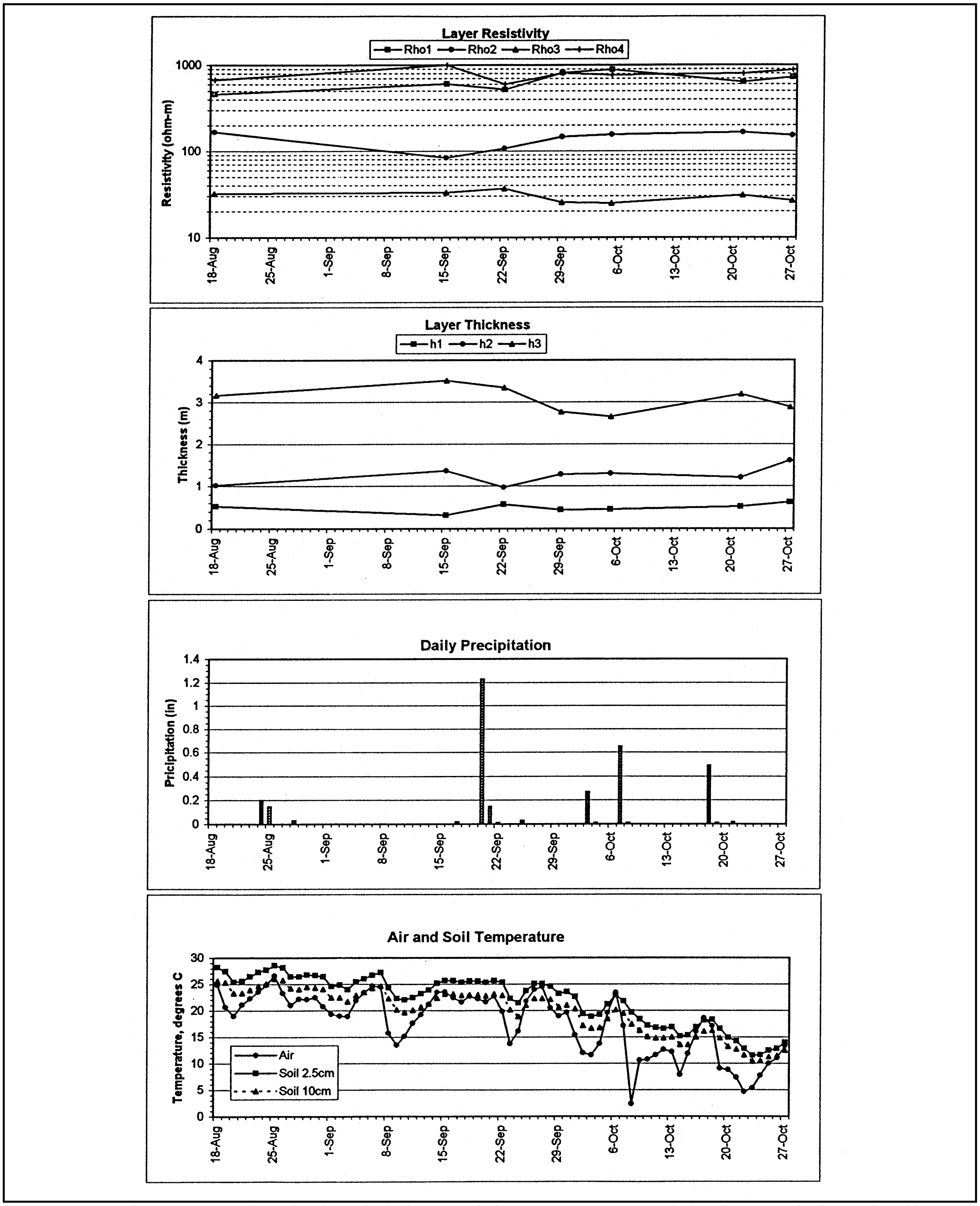


Figure 14. Electrical resistivity model parameters, precipitation, and air and soil temperature as a function of date during the Phase IV demonstrations

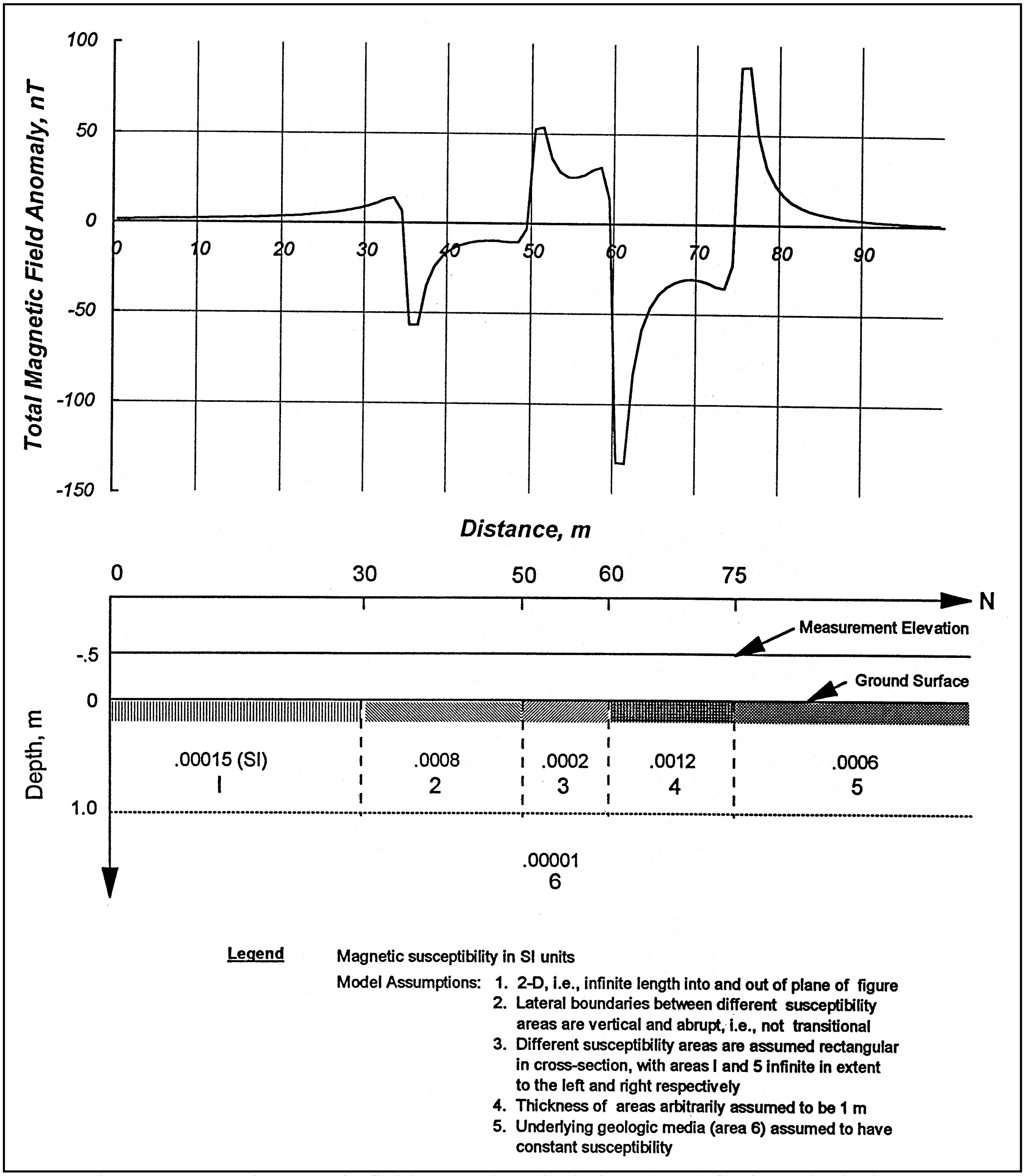


Figure 15. Total magnetic field anomaly calculations (2-D) for hypothetical model of susceptibility along line K based on susceptibility measurements (see Figure 13)

4.1.2 Discrimination

There is no single graph that can explain or show the complete results and complexities from JPG Phase IV. Generally comparing TP versus TN for all areas (Graph 4.1 -1) is a good indicator. Performance on an area by area basis provides additional insight. The following table, Table 4.1-2, is a ranking of the top four performers from all areas and from each of the four areas. The ranking is based on the ability to get closest to the performance goal (top right corner of the graph) parameters and exceeding the 95% confidence boundary (the area enclosed by the green curves).

Table 4.1 - 2 - Summary of TP versus TN Graphs (Top Four Performers)

		Ranking			
Graph	**AREA**	**1st**	**2nd**	**3rd**	**4th**
4.1-1	all	Geophex	NRL	Geo-Centers	ADI
4.1-2	1	Geophex	n.c.	n.c.	n.c.
4.1-3	2	NAEVA	NRL	Geo-Centers	Geophex
4.1-4	3	Geophex	ADI	n.c.	n.c.
4.1-5	4	Geophex	n.c.	n.c.	n.c.

n.c. – no choice (no vendor could reach 95% confidence interval)

Of the four areas surveyed, Geophex showed the best performance in three. Although Geophex's performance did not drop in area 2 as compared to other areas, why did three other demonstrators perform better in that area? For that matter, why did NAEVA show well in area 2 and nowhere else? All these vendors use Mag, EM (or GEM) exclusively yet discrimination performance was erratic and/or area specific. The only observable difference between area 2 and the other areas can be seen in the electromagnetic terrain conductivity maps produced by the Geonics EM-31 (figure 16). It appears that the conditions in area 2 are relatively isotropic in the dry season compared to conditions in the rest of the areas. Of course sample population, data quality, and subjective analysis all play a role in final decision making.

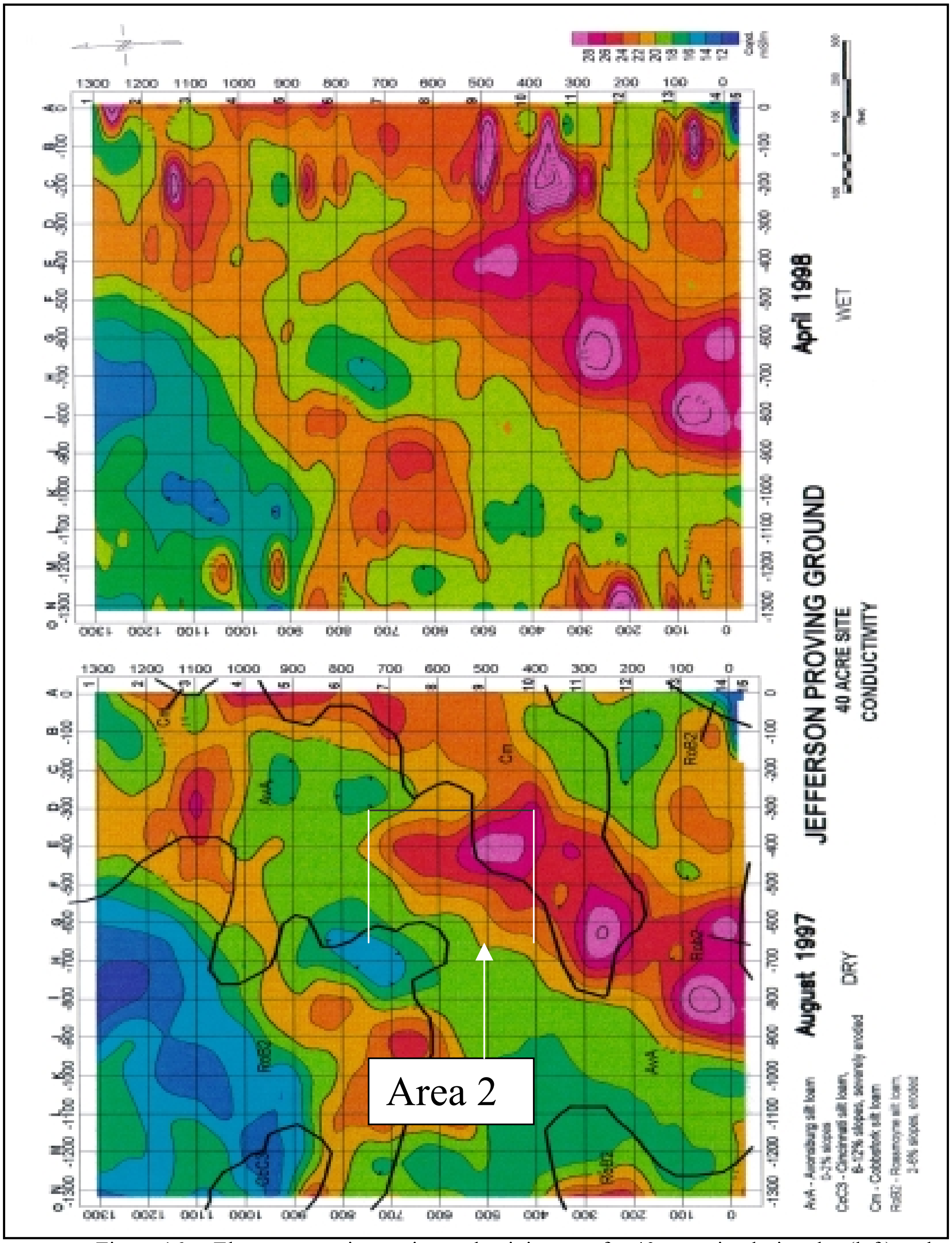


Figure 16. Electromagnetic terrain conductivity map for 40-acre site during dry (left) and wet (right) site conditions; determined with Geonics EM-31 (frequency domain EM induction system, 9.8 kHz)

Confidence declarations are an important metric and demonstrate vendor assertions in their own abilities. When viewing confidence graphs (4.1 – 11 to 13) the viewer should look for a high percentage of correct confidence declarations in the "high" confidence region, with decreasing percentages in the follow-on confidence categories. Table 4.1-4 shows confidence performance by the top four performers.

Table 4.1 - 3 , Summary of Confidence Declaration Graphs (Top Four Performers)

		Ranking			
Graph	**Areas**	**1st**	**2nd**	**3rd**	**4th**
4.1 -11	Ordnance & Non-Ordnance	Geophex	SC&A	NRL	NAEVA
4.1 - 12	Ordnance Only	Geophex	SC&A	n.c.	n.c.
4.1 - 13	Non-Ordnance Only	Geophex	SC&A	NAEVA	GTL
n.c. – no choice					

The combined percentage of correct ordnance and non-ordnance discriminations is shown in graph 4.1-14. Geophex, ADI, and NRL were the top performers.

Time On Grid is an important metric in the detection and survey mode Sensors and systems that can be used for both discrimination and rapid surveys are highly desirable. Cost reductions in terms of survey time have favored the vehicular systems and JPG Phase IV is no exception. Graph 4.1 – 16 shows that the most efficient performers were Geo-Centers, NRL, SC&A, and Battelle which all used some sort of rolling platform. However, it should be noted that "time on grid" is biased due to the fact that a demonstrator may have actually, for example, surveyed all the targets in 20 hours and chosen the remaining time to research other objectives.

Ranking declarations (1 being most likely ordnance to 160 being most likely non-ordnance) were required from all demonstrators. Graphs 4.1 - 17 & 18 show the results of this requirement. The red line with a slope of "1" represents perfect discrimination. For ordnance rank order Geophex showed an almost perfect ordering for the first 20 declarations and for non-ordnance showed a perfect ordering of the first 30 declarations. Although Geo-Centers showed the best TP rate of over 80%, graph 4.1 - 17 shows that much of this success was based on declaring most of the targets as ordnance (115 declarations of ordnance versus 50 actual ordnance targets buried). On a real range this would cause unwarranted remediation costs.

Table 4.1 - 5 shows ordnance discrimination by demonstrator. From this table it can be seen that the most difficult ordnance targets to discriminate were the 20mm and 152mm projectiles and 81mm unfuzed mortars[2], given the assumption that all items were detectable. If a range contaminated with 20mm projectiles were a problem, Geophex would be a vendor to consider since they found every 20mm round and correctly identified, not only it as ordnance, but also the particular class of ordnance. If 105mm and 155mm projectiles are important then NAEVA or possibly Geo-Centers could help

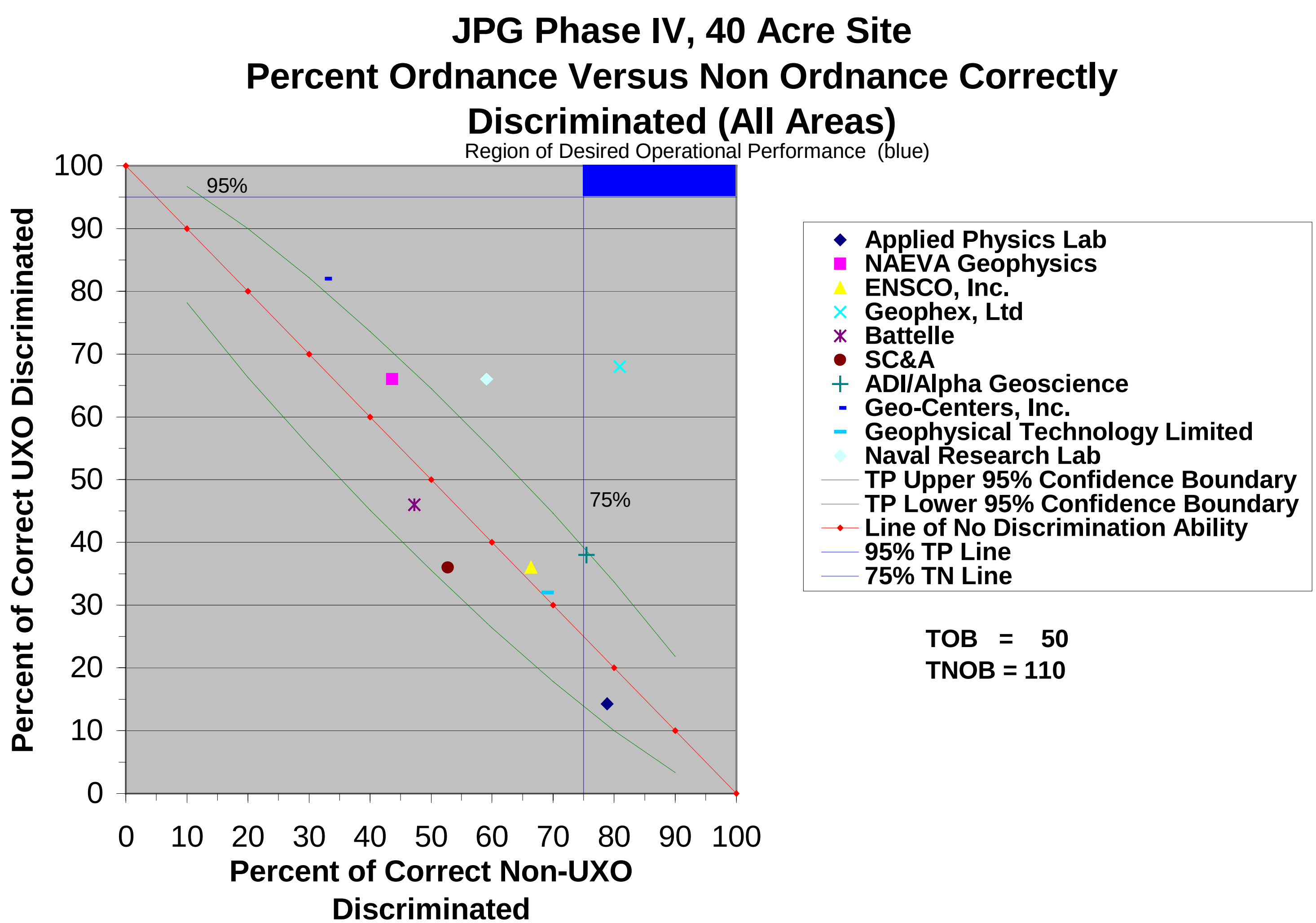
[2] Determined by the number of correct declarations divided by the number of ordnance items in a particular class (e.g. 19 correct 20mm declarations were made divided by 5 items buried = 3.8)

(keeping in mind their high ordnance declaration rate). Graph 4.1-20 shows the frequency of correct discriminations by target number and separated by area.

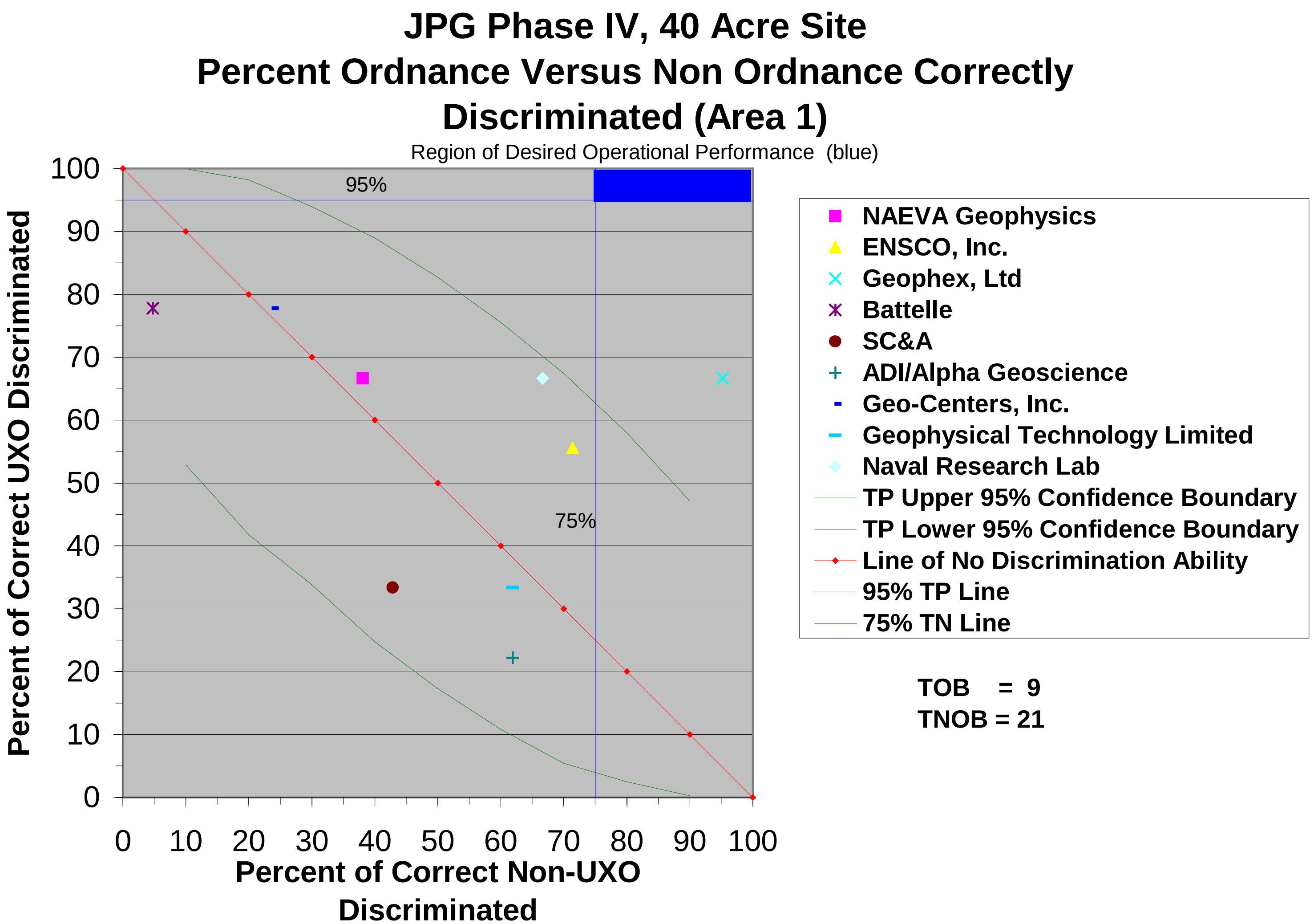
The last important figure of merit involves the process of not only determining whether an anomaly is ordnance or non-ordnance, but, if it's ordnance, what type it is (e.g. 60mm mortar, 20mm projectile). Graph 4.1- 9 shows that Geophex was able to declare the actual ordnance item in a little over 55% of the time while NRL, followed by NAEVA, were able to identify particular ordnance targets around 30% of the time.

Size, weight, depth error, and class are presented as graphs 4.1-21 to 4.1-24 but not discussed. Graph 4.1-26 depicts target depth versus target volume and graphed logarithmically. Delineations are made between ordnance and non-ordnance as well as discrimination difficulty. This graph is an indication of how well the targets were buried to achieve a credible signal to noise ratio from sensors demonstrated. Three or four of the ordnance targets were placed at or near their maximum burial depth for the sensors used during Phase IV. Performance by individual vendors, depicting target depths versus target volume can be found in Appendix A along with each vendor's performance on an area by area basis. Appendix C provides the final reports by each demonstrator regarding their system and reported demonstration performance.

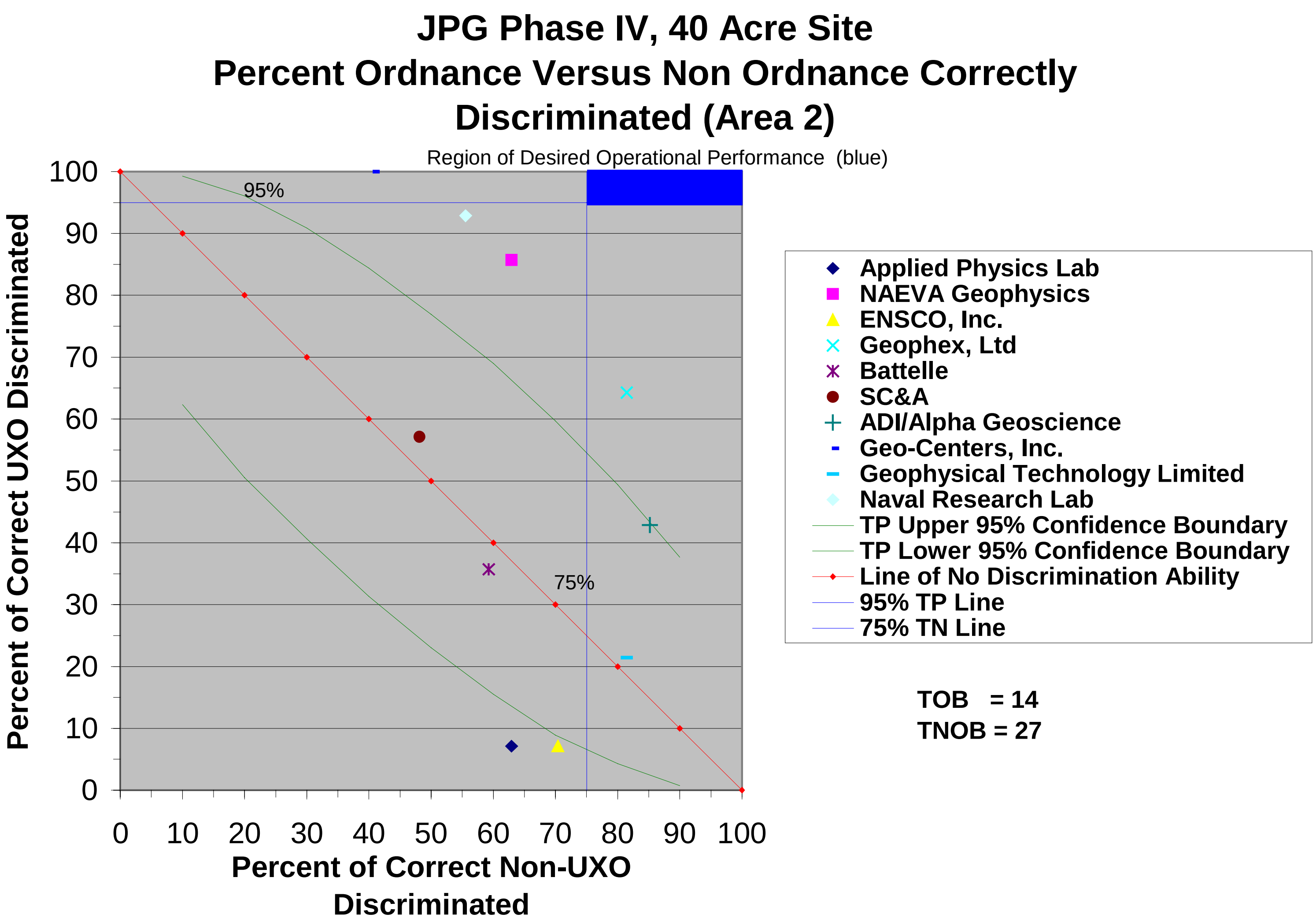
Graph 4.1 - 1 , TP versus TN (All Areas)



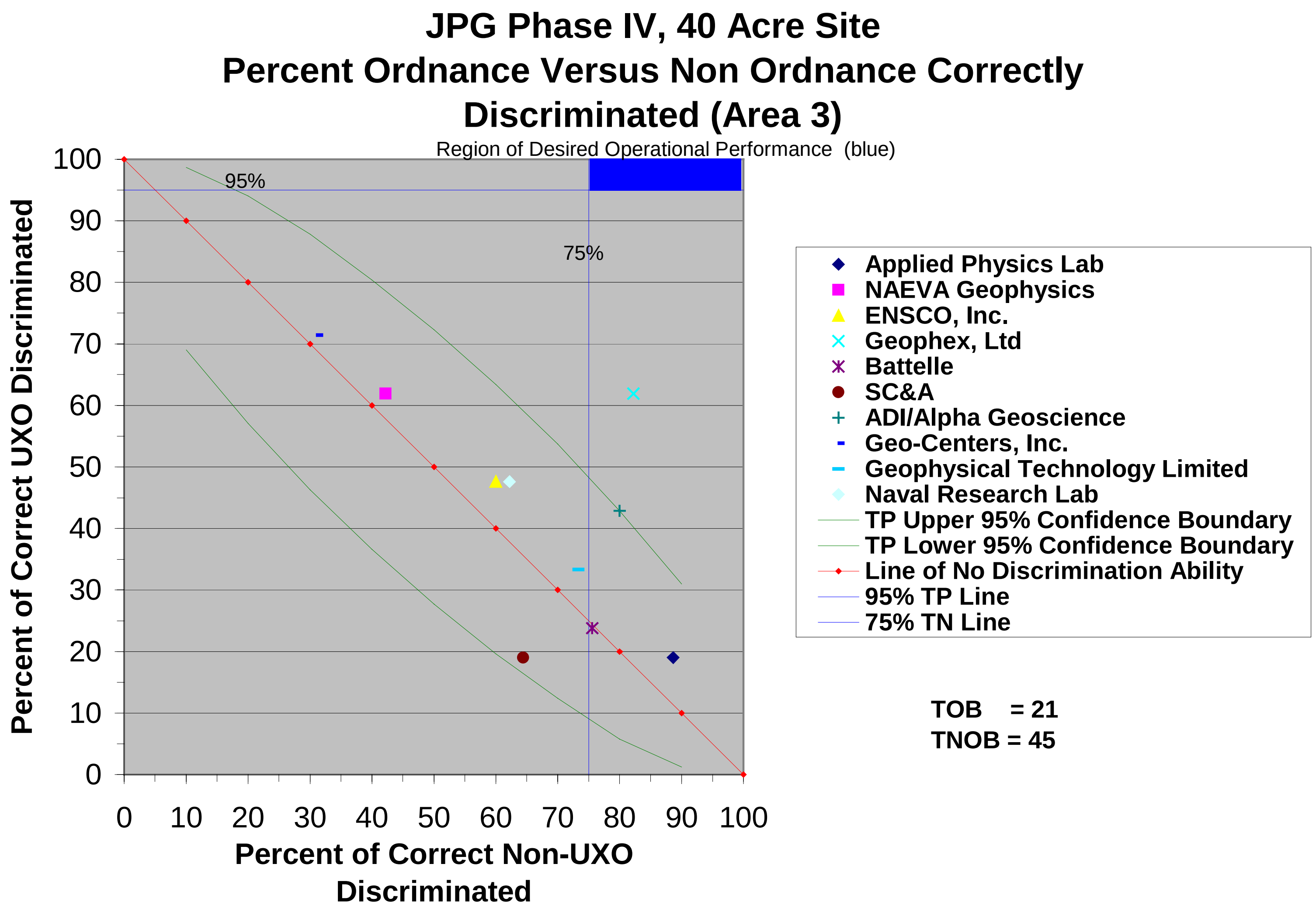
Graph 4.1 - 2 , TP versus TN (Area 1)



Graph 4.1 - 3 , TP versus TN (Area 2)

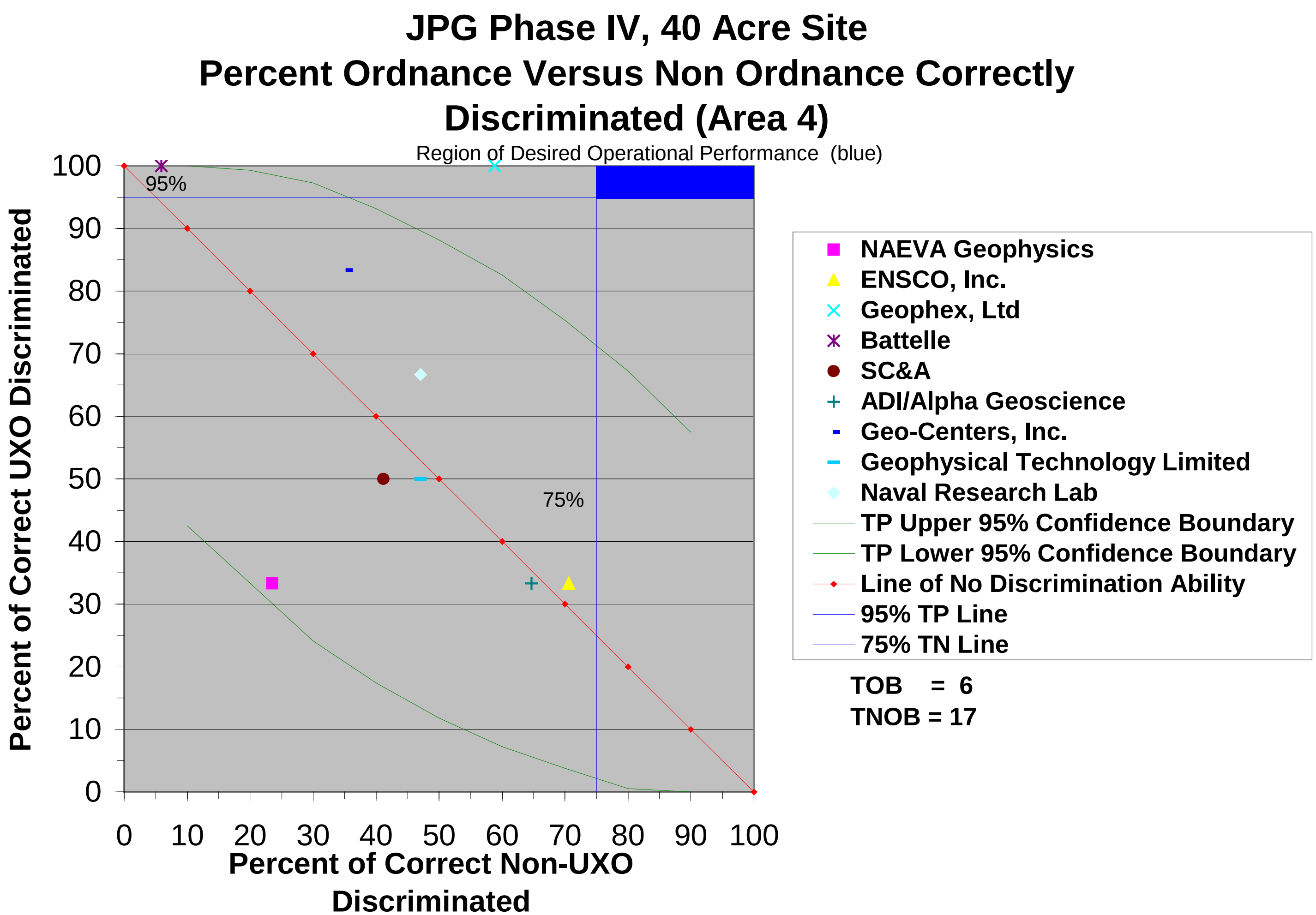


Graph 4.1 - 4 , TP versus TN (Area 3)

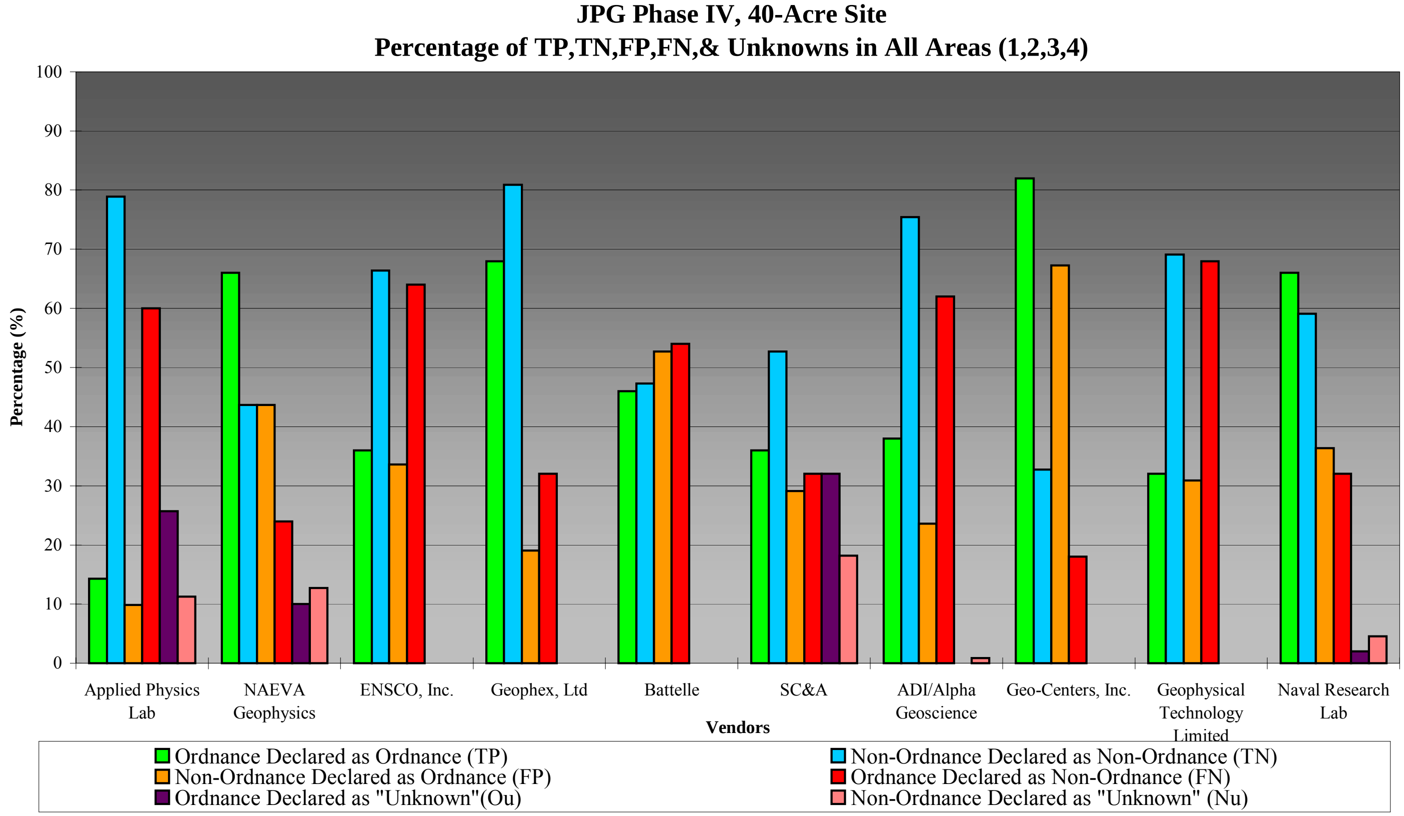


TOB = 21
TNOB = 45

Graph 4.1 - 5 , TP versus TN (Area 4)



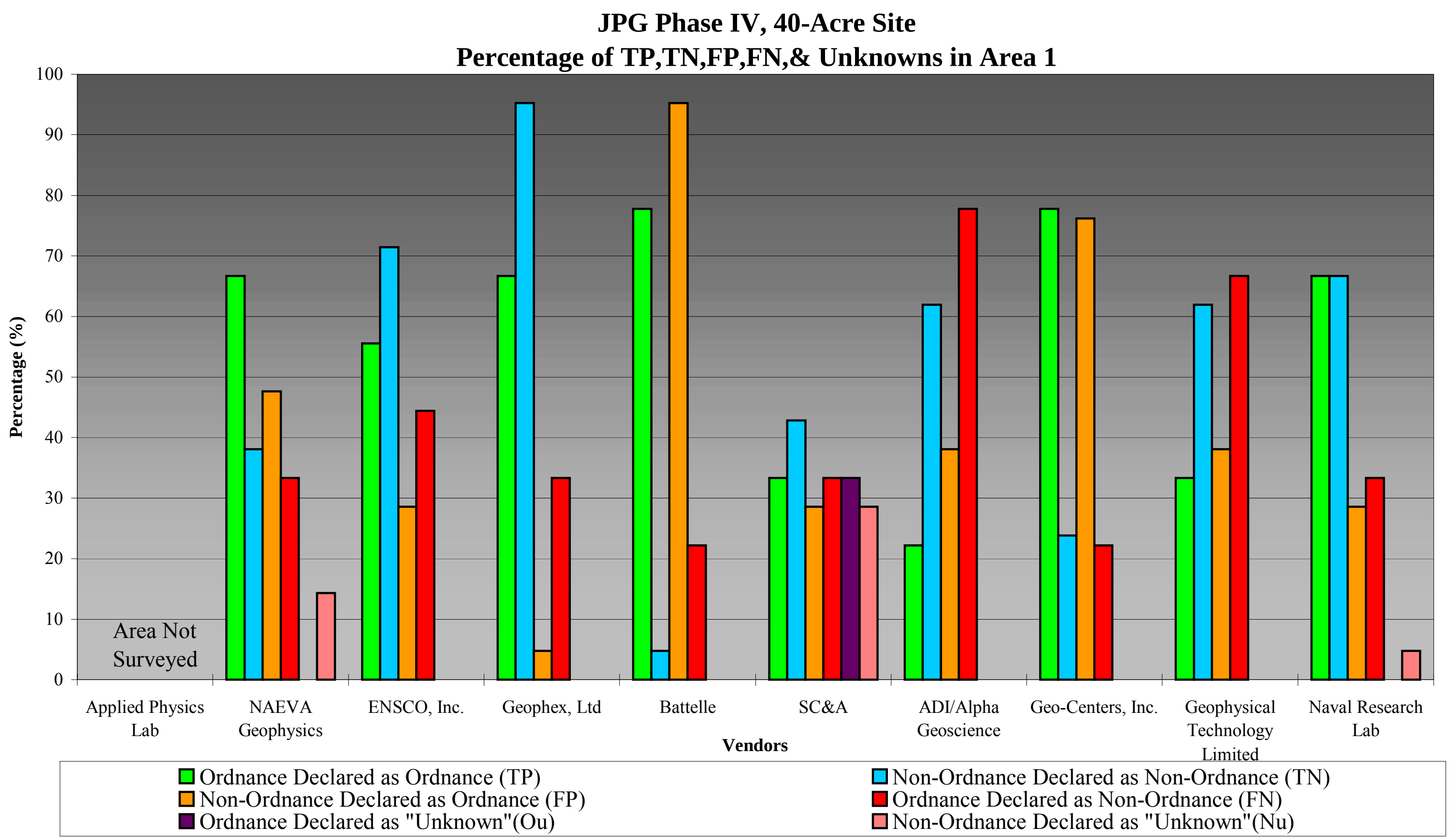
Graph 4.1 - 6 , TP, TN, FP, FN (All Areas)



APL - TOB=35, TNOB=71, Ou=9, Nu=8, not surveyed=54
SC&A - TOB=50, TNOB=110, ? u=16, Nu=20
NRL - TOB=50, TNOB=110, Ou=1, Nu=5
NAEVA - TOB=50, TNOB=110, Ou=5, Nu=14
ADI - TOB=50, TNOB=110, Ou=0, Nu=1
All Others - TOB=50, TNOB=110, Ou=0, Nu=0

%TP = (Correct Ordnance Declarations / TOB) x 100
%TN = (Correct Non-Ordnance Declarations / TNOB) x 100
%FP = (Non-Ordnance Declared as Ordnance / TNOB) x 100
%Ou = (Ordnance Declared as Unknown / TOB) x 100
%Nu = (Non-Ordnance Declared as Unknown / TNOB) x 100
%FN = (Ordnance Declared as Non-Ordnance / TOB) x 100

Graph 4.1 - 7 , TP, TN, FP, FN (Area 1)

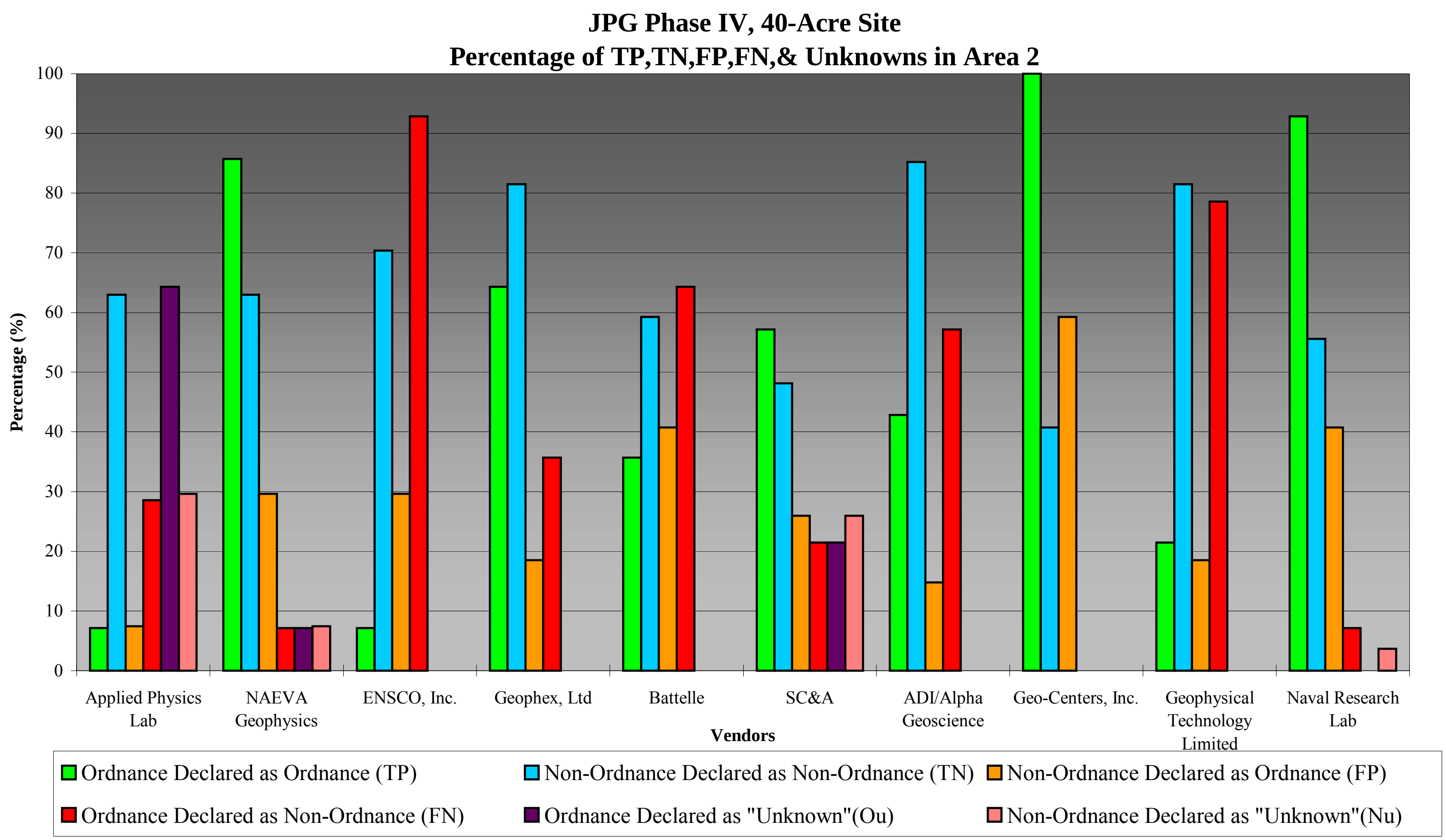


APL - TOB=9, TNOB=21, Ou=0, Nu=0, not surveyed=30
NAEVA - TOB=9, TNOB=21, Ou=0, Nu=3
SC&A - TOB=9, TNOB=21, Ou=3, Nu=6
ADI - TOB=9, TNOB=21, Ou=0, Nu=0
NRL - TOB=9, TNOB=21, Ou=0, Nu=1
All Others - TOB=9, TNOB=21, Ou=0, Nu=0

%TP = (Correct Ordnance Declarations / TOB) x 100
%TN = (Correct Non-Ordnance Declarations / TNOB) x 100
%FP = (Non-Ordnance Declared as Ordnance / TNOB) x 100

%Ou = (Ordnance Declared as Unknown / TOB) x 100
%Nu = (Non-Ordnance Declared as Unknown / TNOB) x 100
%FN = (Ordnance Declared as Non-Ordnance / TOB) x 100

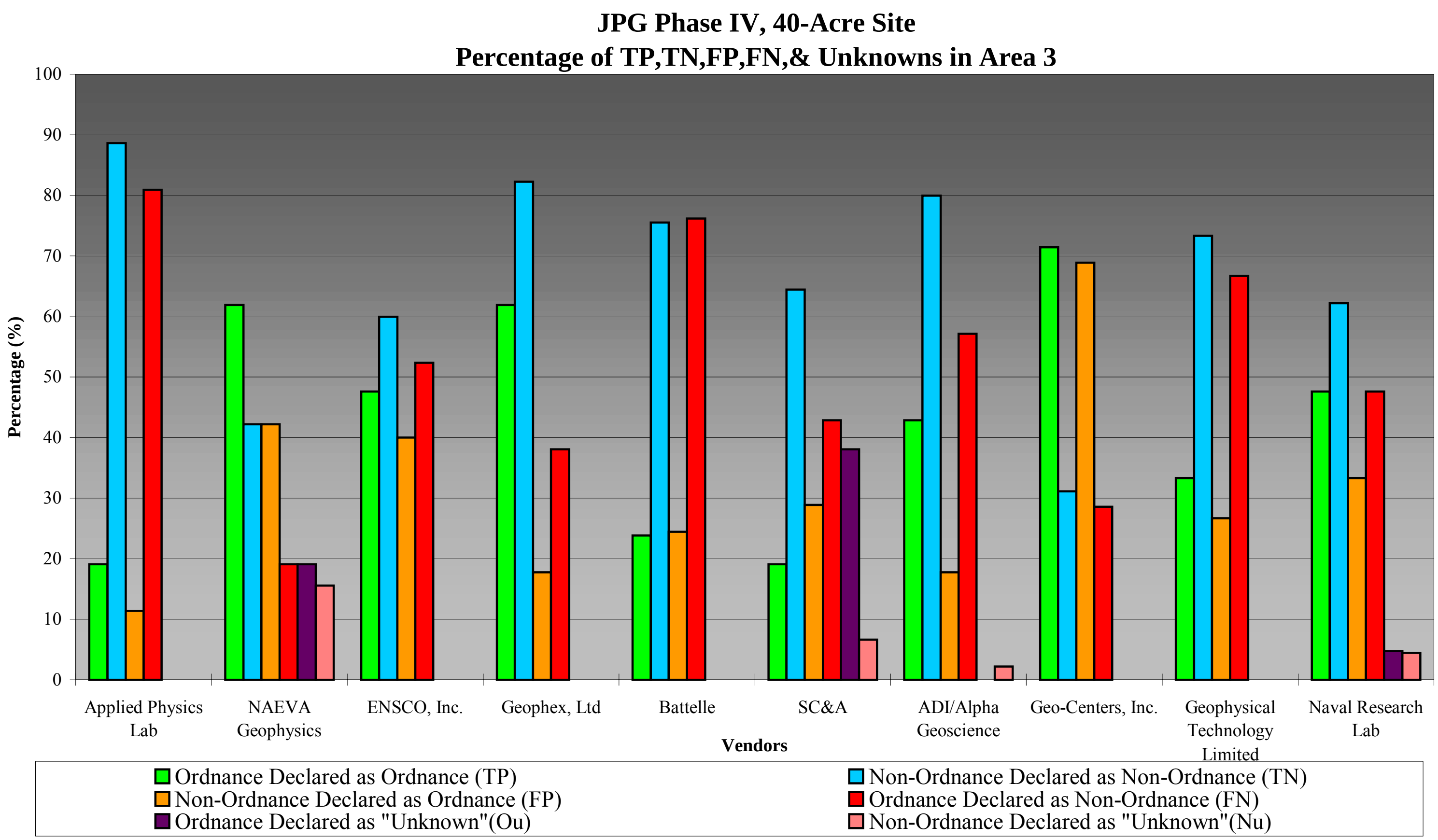
Graph 4.1 - 8 , TP, TN, FP, FN (Area 2)



APL - TOB=14, TNOB=27, Ou=9, Nu=8, not surveyed=
NAEVA - TOB=14, TNOB=27, Ou=1, Nu=2
SC&A - TOB=14, TNOB=27, Ou=3, Nu=7
ADI - TOB=14, TNOB=27, Ou=0, Nu=0
NRL - TOB=14, TNOB=27, Ou=0, Nu=1
All Others - TOB=14, TNOB=27, Ou=0, Nu=0

%TP = (Correct Ordnance Declarations / TOB) x 100
%TN = (Correct Non-Ordnance Declarations / TNOB) x 100
%FP = (Non-Ordnance Declared as Ordnance / TNOB) x 100
%Ou = (Ordnance Declared as Unknown / TOB) x 100
%Nu = (Non-Ordnance Declared as Unknown / TNOB) x 100
%FN = (Ordnance Declared as Non-Ordnance / TOB) x 100

Graph 4.1 - 9 , TP, TN, FP, FN (Area 3)



APL - TOB=21, TNOB=44, Ou=0, Nu=0, not surveyed=1

NAEVA - TOB=21, TNOB=45, Ou=4, Nu=7

SC&A - TOB=21, TNOB=45, Ou=8, Nu=3

ADI - TOB=21, TNOB=45, Ou=0, Nu=1

NRL - TOB=21, TNOB=45, Ou=1, Nu=2

All Others - TOB=21, TNOB=45, Ou=0, Nu=0

%TP = (Correct Ordnance Declarations / TOB) x 100

%TN = (Correct Non-Ordnance Declarations / TNOB) x 100

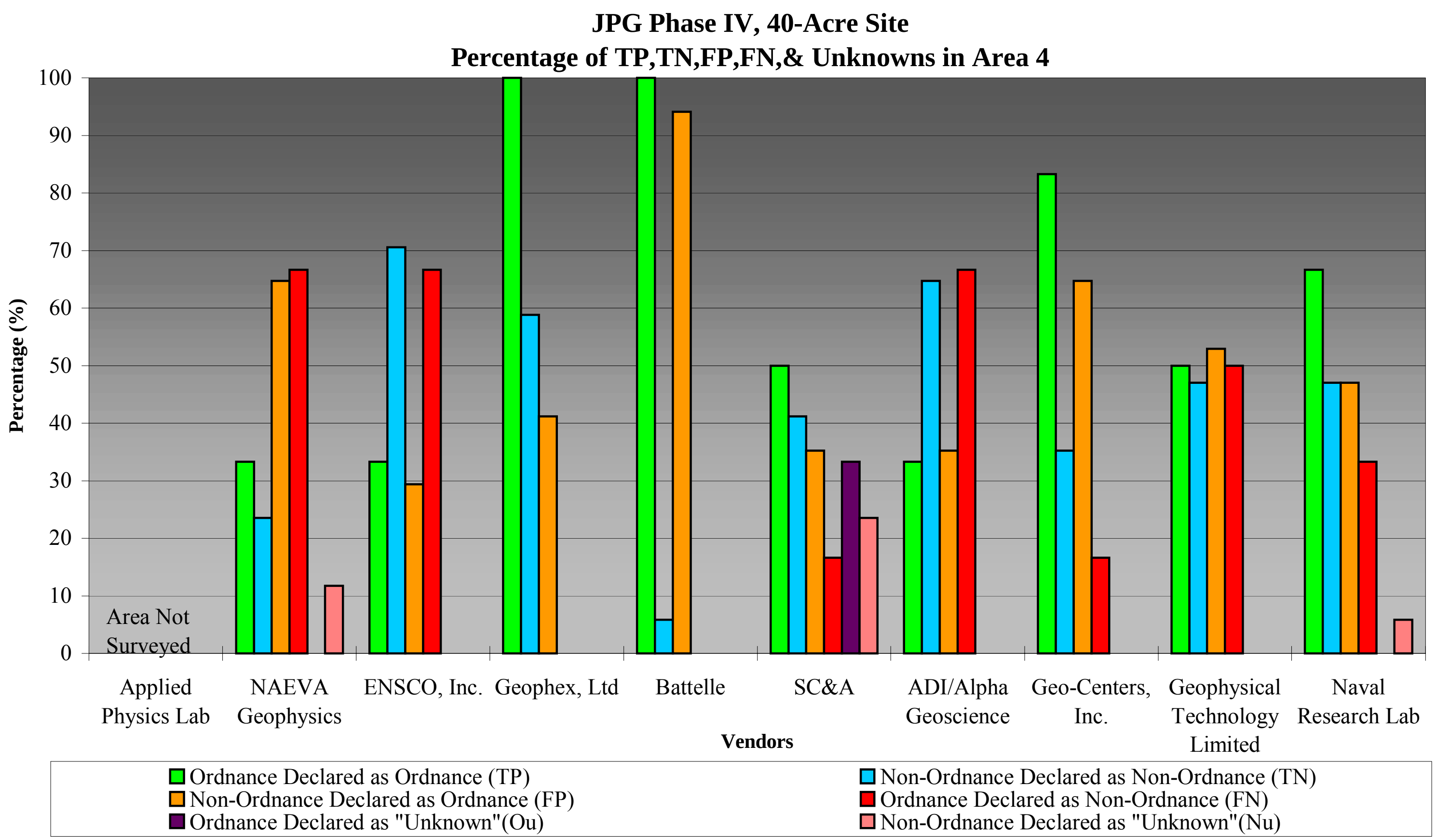
%FP = (Non-Ordnance Declared as Ordnance / TNOB) x 100

%Ou = (Ordnance Declared as Unknown / TOB) x 100

%Nu = (Non-Ordnance Declared as Unknown / TNOB) x 100

%FN = (Ordnance Declared as Non-Ordnance / TOB) x 100

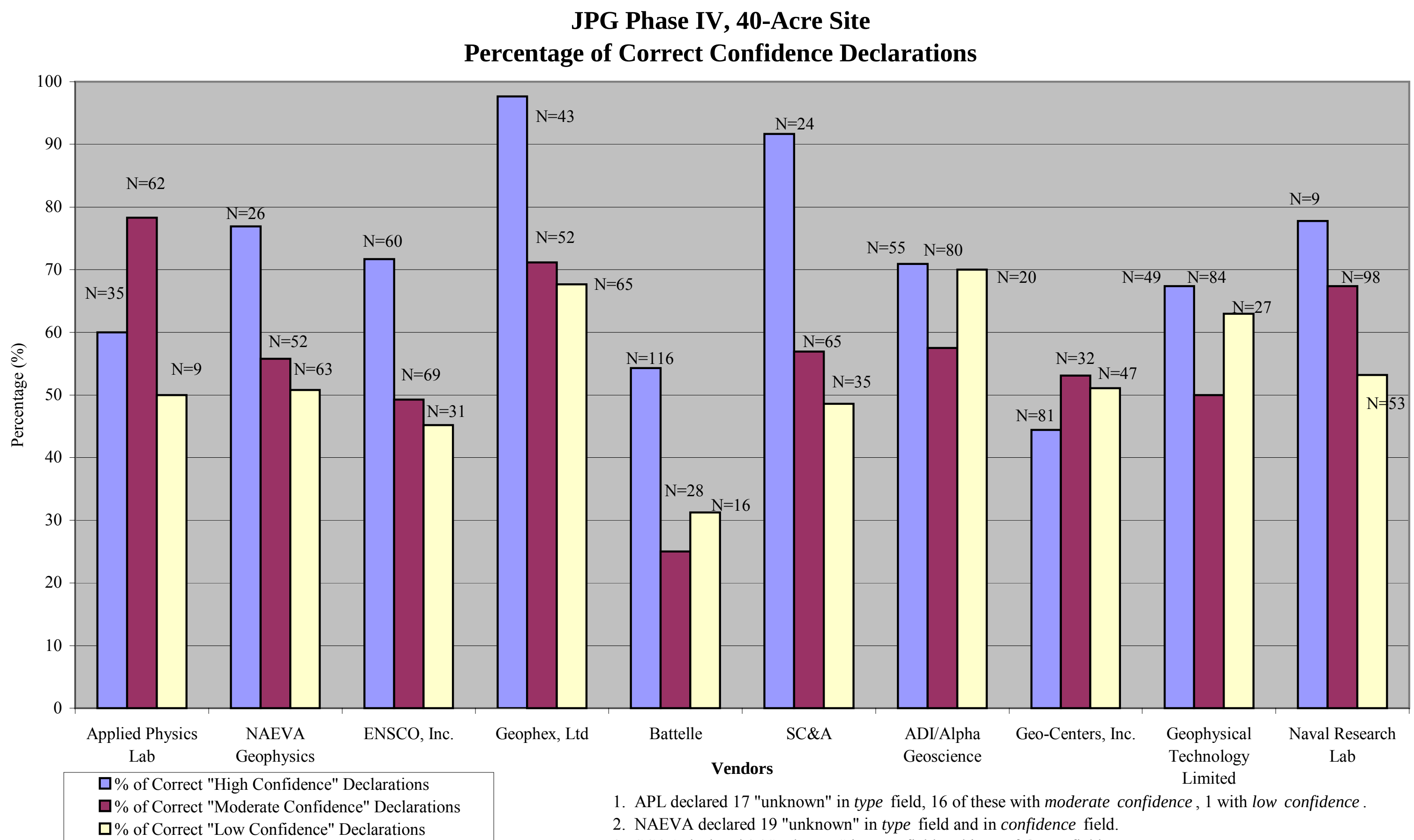
Graph 4.1 - 10 , TP, TN, FP, FN (Area 4)



APL - TOB=6, TNOB=17, Ou=0, Nu=0, not surveyed=23
NAEVA - TOB=6, TNOB=17, Ou=0, Nu=2
SC&A - TOB=6, TNOB=17, Ou=2, Nu=4
ADI - TOB=6, TNOB=17, Ou=0, Nu=0
NRL - TOB=6, TNOB=17, Ou=0, Nu=1
All Others - TOB=50, TNOB=110, Ou=0, Nu=0

%TP = (Correct Ordnance Declarations / TOB) x 100
%TN = (Correct Non-Ordnance Declarations / TNOB) x 100
%FP = (Non-Ordnance Declared as Ordnance / TNOB) x 100
%Ou = (Ordnance Declared as Unknown / TOB) x 100
%Nu = (Non-Ordnance Declared as Unknown / TNOB) x 100
%FN = (Ordnance Declared as Non-Ordnance / TOB) x 100

Graph 4.1 - 11 , Confidence Declarations (Ordnance and Non-Ordnance Combined)

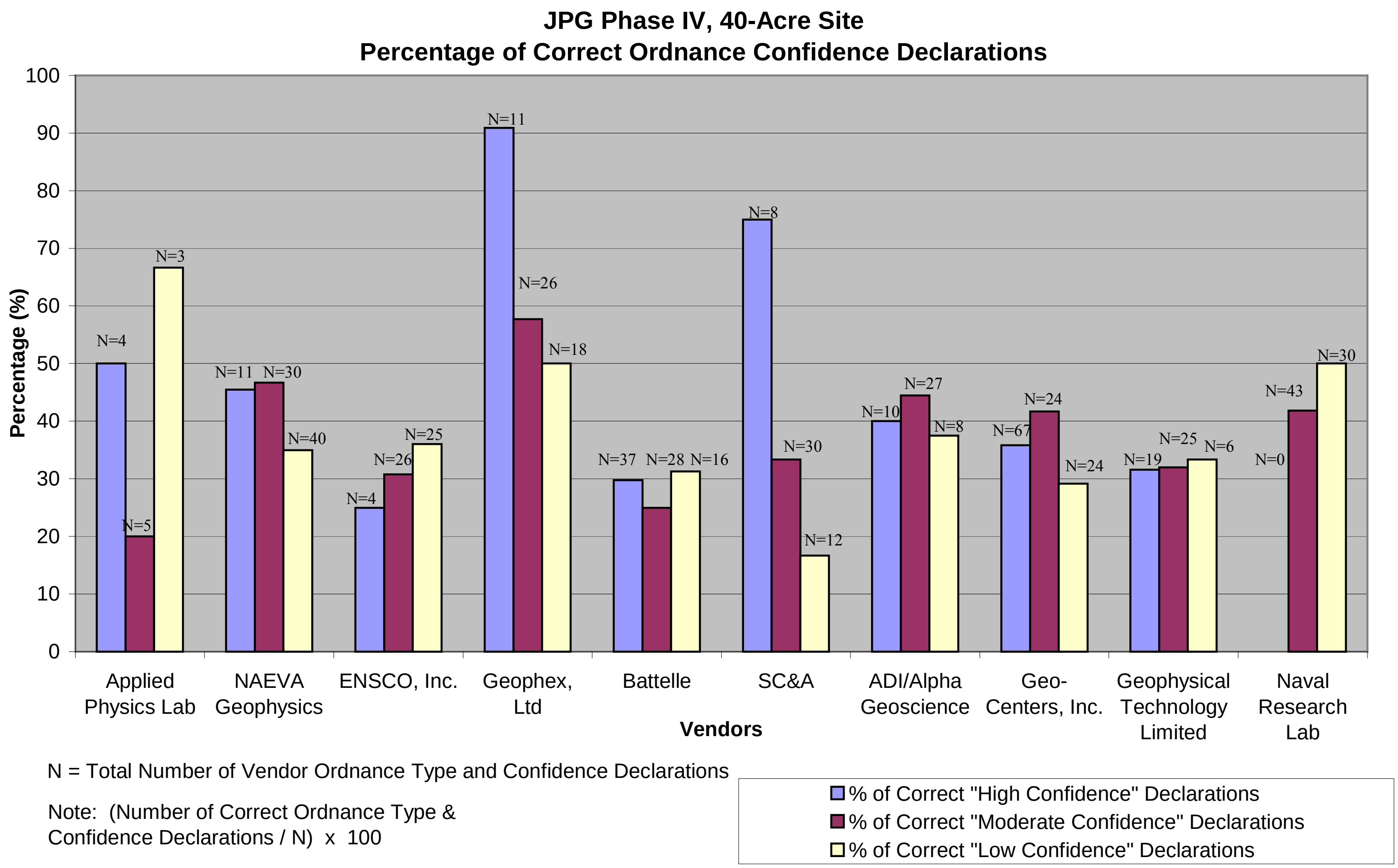


Note: (Number of Particular Confidence Level Declarations, where Correct Ordnance or Non-Ordnance Declarations were made / Total Number of Particular Confidence Level Declarations made) x 100

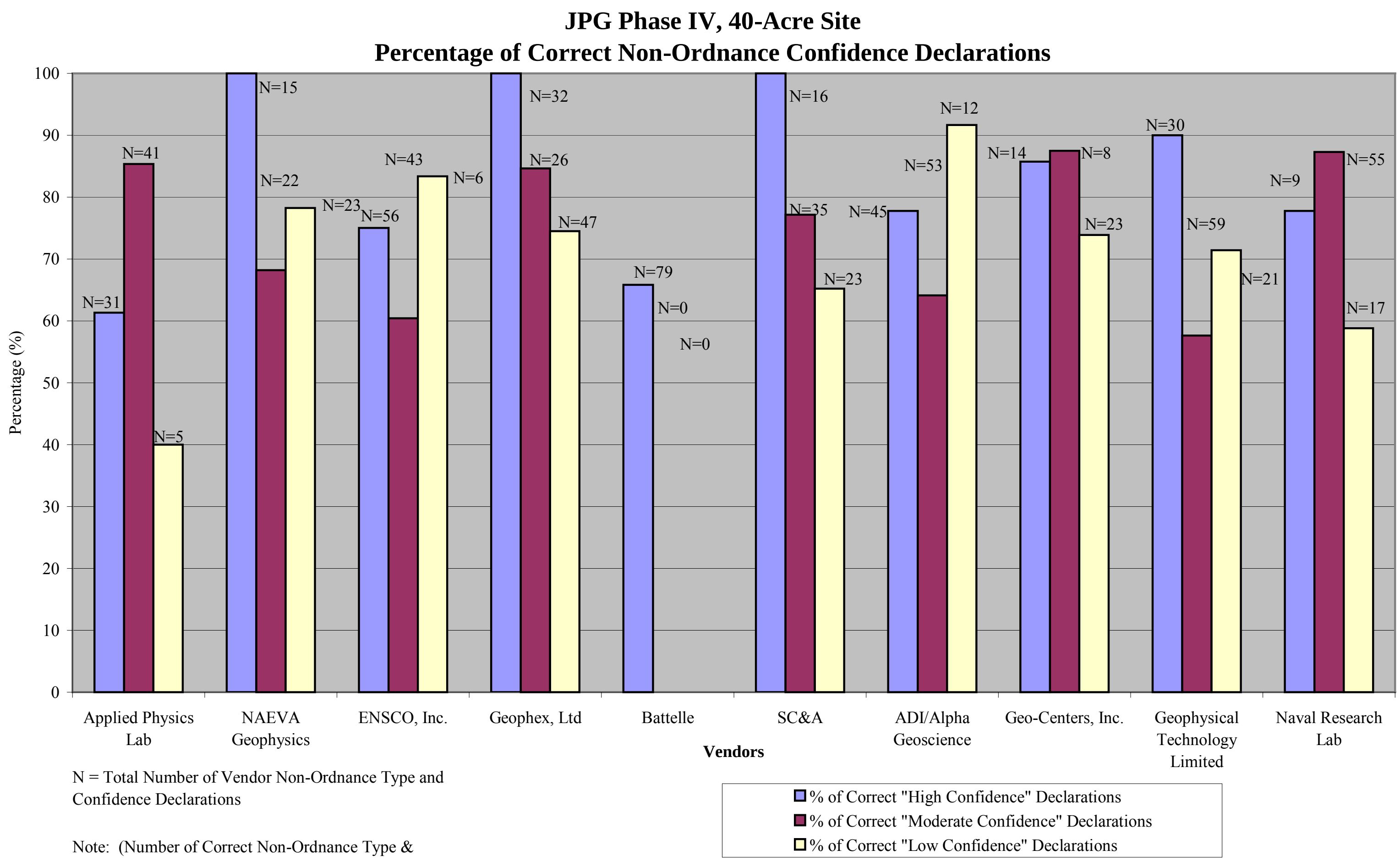
1. APL declared 17 "unknown" in *type* field, 16 of these with *moderate confidence*, 1 with *low confidence*.
2. NAEVA declared 19 "unknown" in *type* field and in *confidence* field.
3. SC&A declared 36 "unknown" in *type* field and in *confidence* field.
4. ADI declared 5 "unknown" in *confidence* field, one of which was declared "unknown" in *type* field.
5. NRL declared 6 "unknown" in type field. All 6 were declared *low confidence*.

N = Total Number of Demonstrator Declarations

Graph 4.1 - 12 , Confidence Declarations (Ordnance Only)



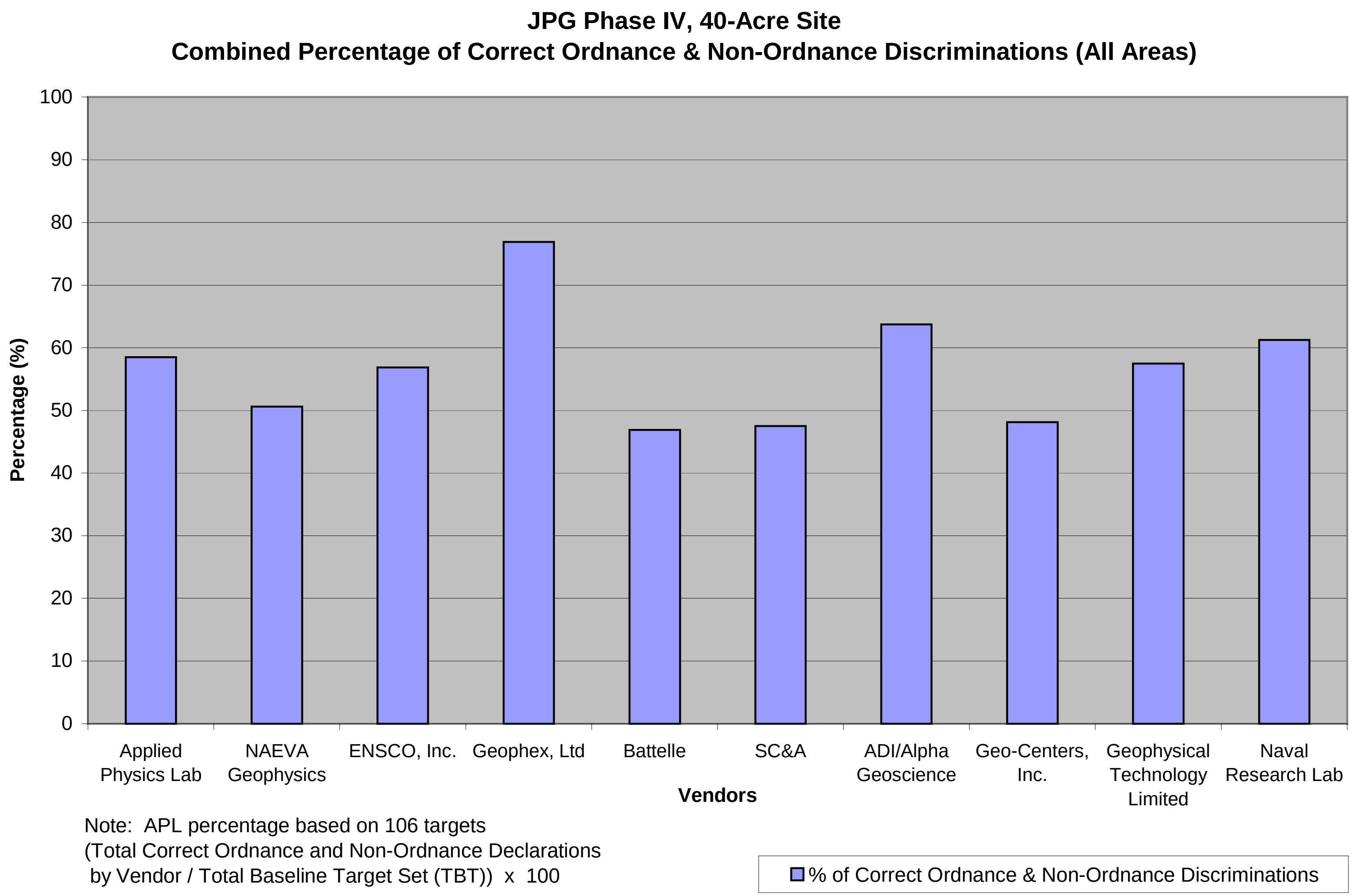
Graph 4.1 - 13 , Confidence Declarations (Non-Ordnance Only)



N = Total Number of Vendor Non-Ordnance Type and Confidence Declarations

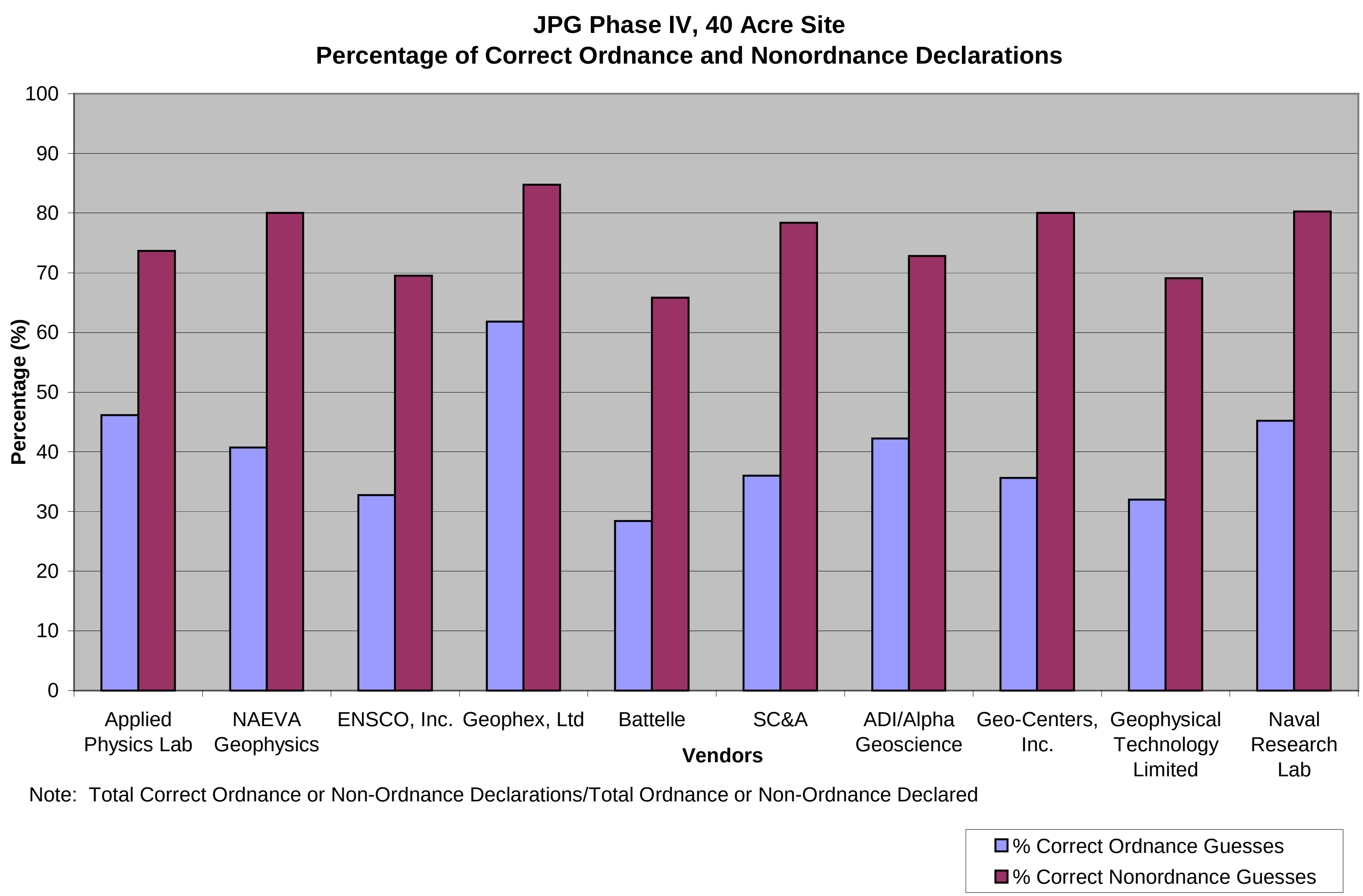
Note: (Number of Correct Non-Ordnance Type & Confidence Declarations / N) x 100

Graph 4.1 - 14 , Discriminations (Ordnance and Non-Ordnance)



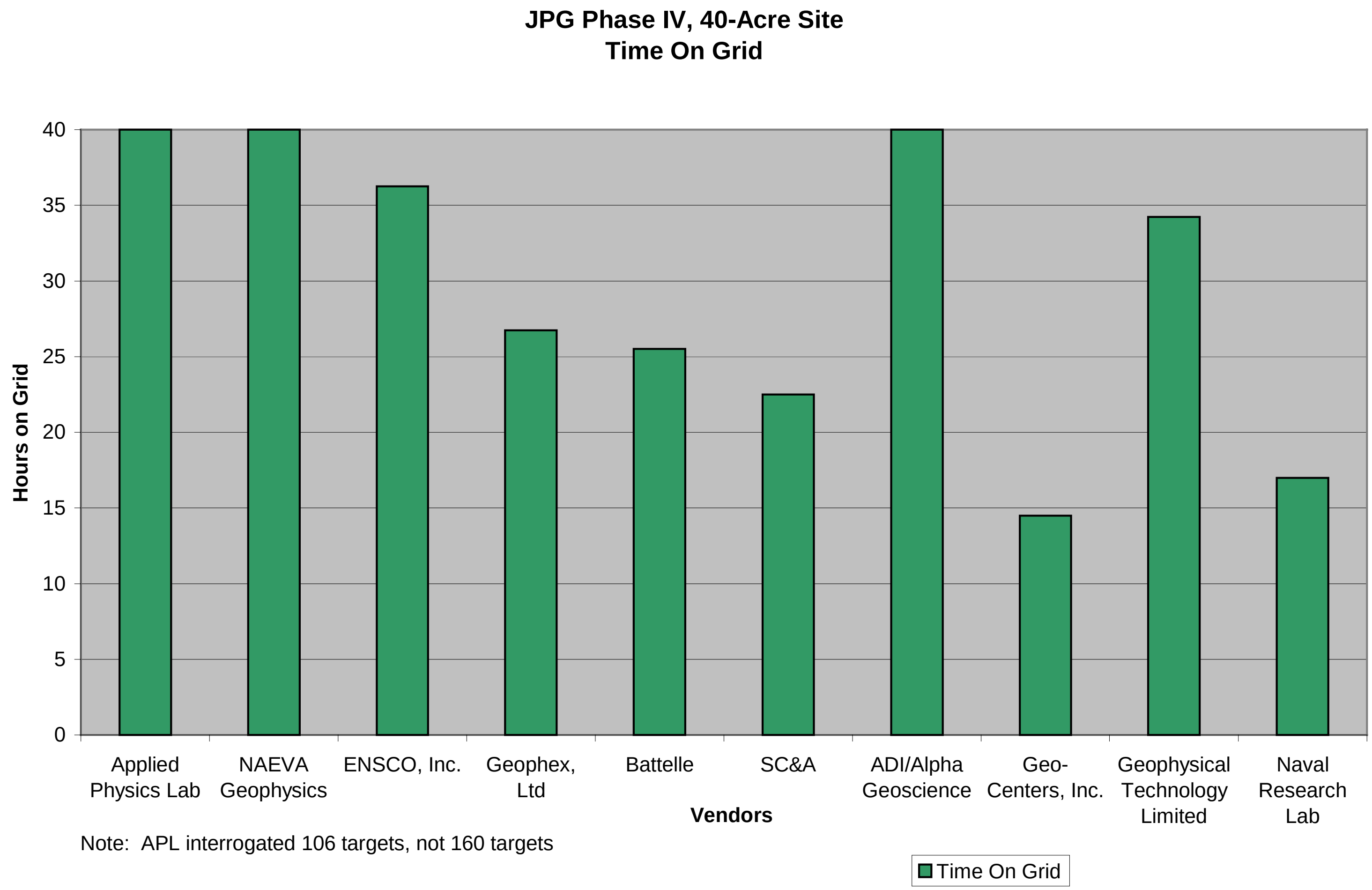
Note: APL percentage based on 106 targets
(Total Correct Ordnance and Non-Ordnance Declarations
by Vendor / Total Baseline Target Set (TBT)) x 100

Graph 4.1 - 15 , Declarations (Ordnance and Non-Ordnance)



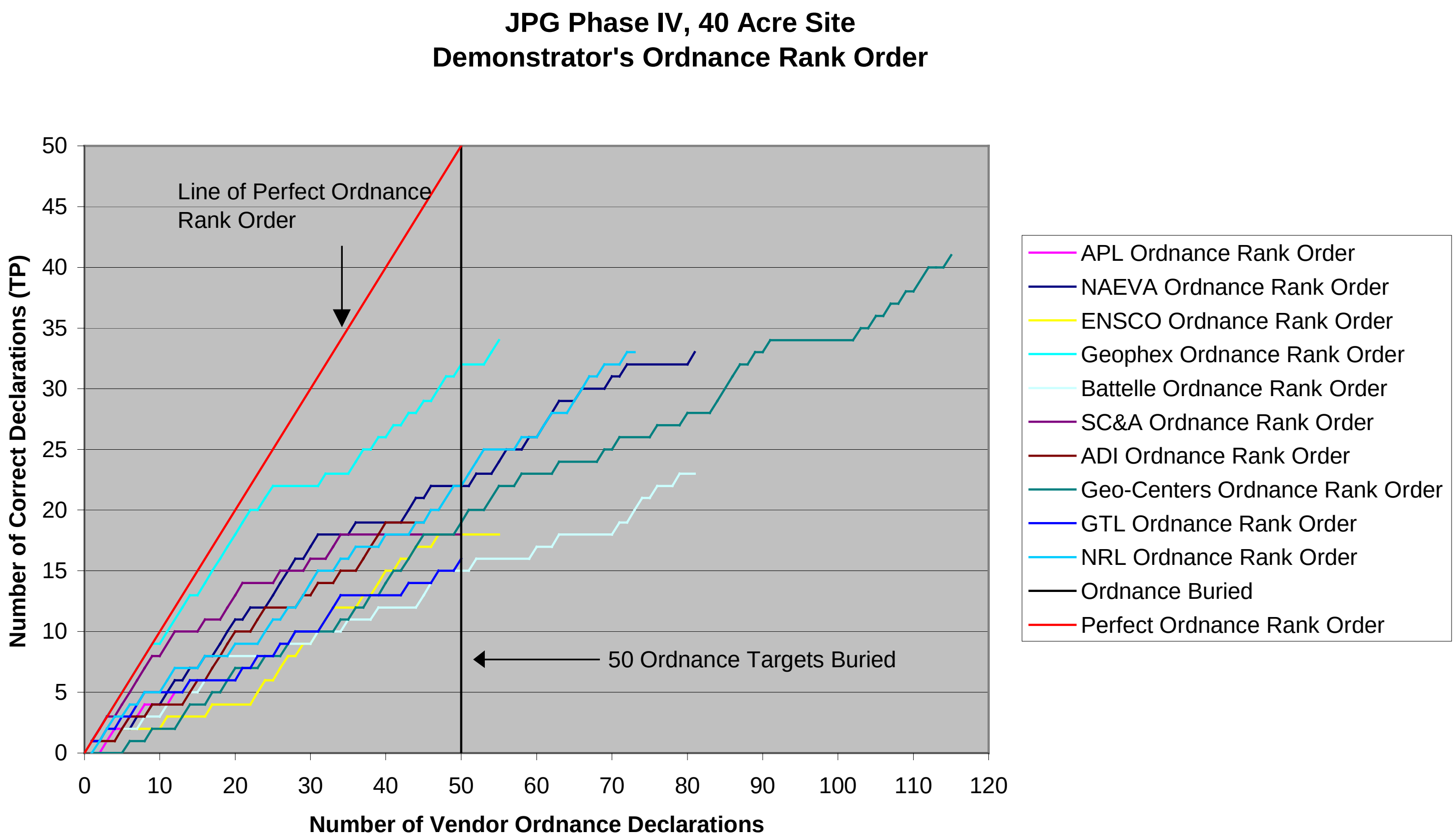
Note: Total Correct Ordnance or Non-Ordnance Declarations/Total Ordnance or Non-Ordnance Declared

Graph 4.1 - 16, Time on Grid



Note: APL interrogated 106 targets, not 160 targets

Graph 4.1 - 17 , Ordnance Rank Order



Graph 4.1 - 18 , Non Ordnance Rank Order

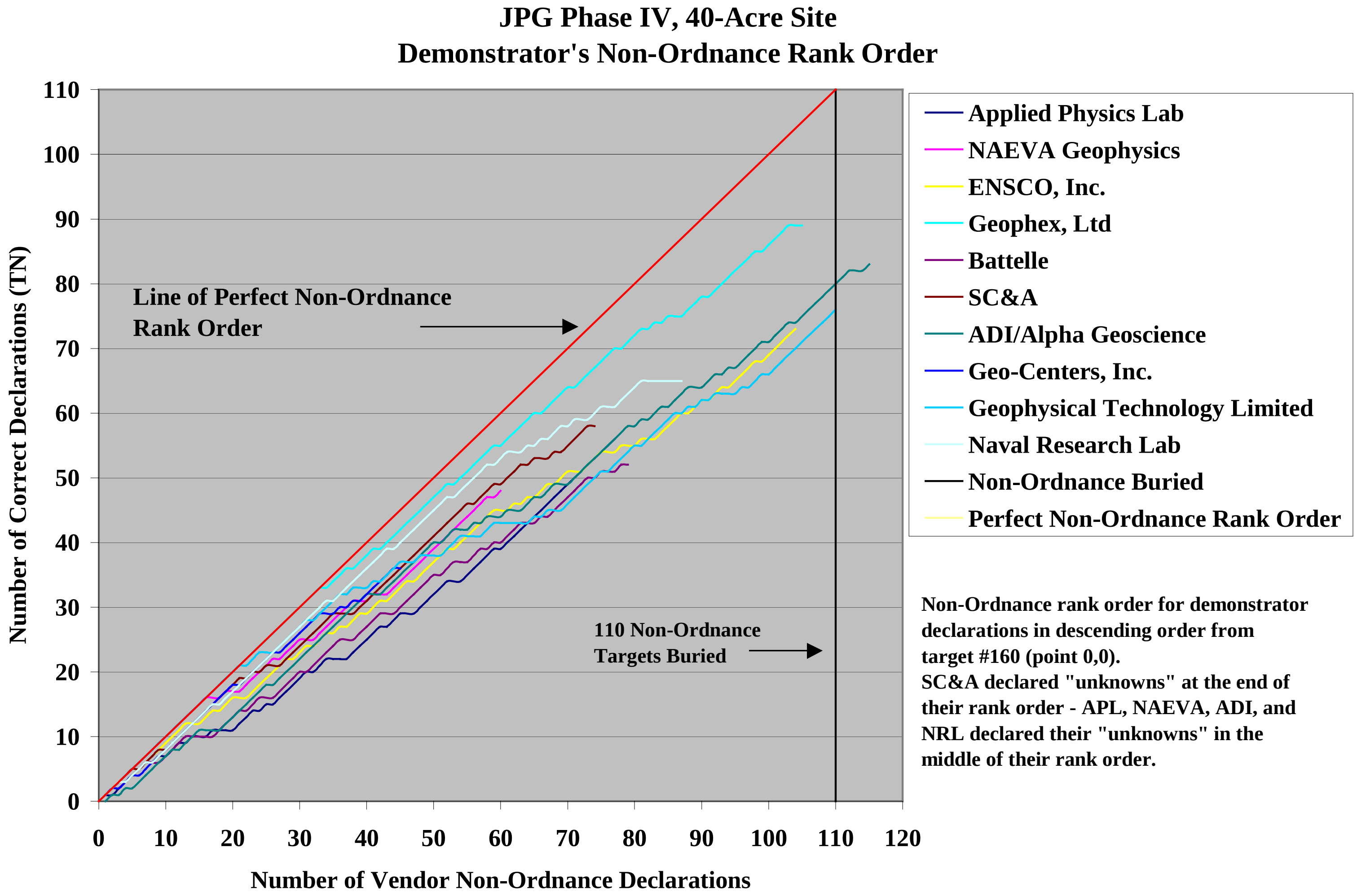
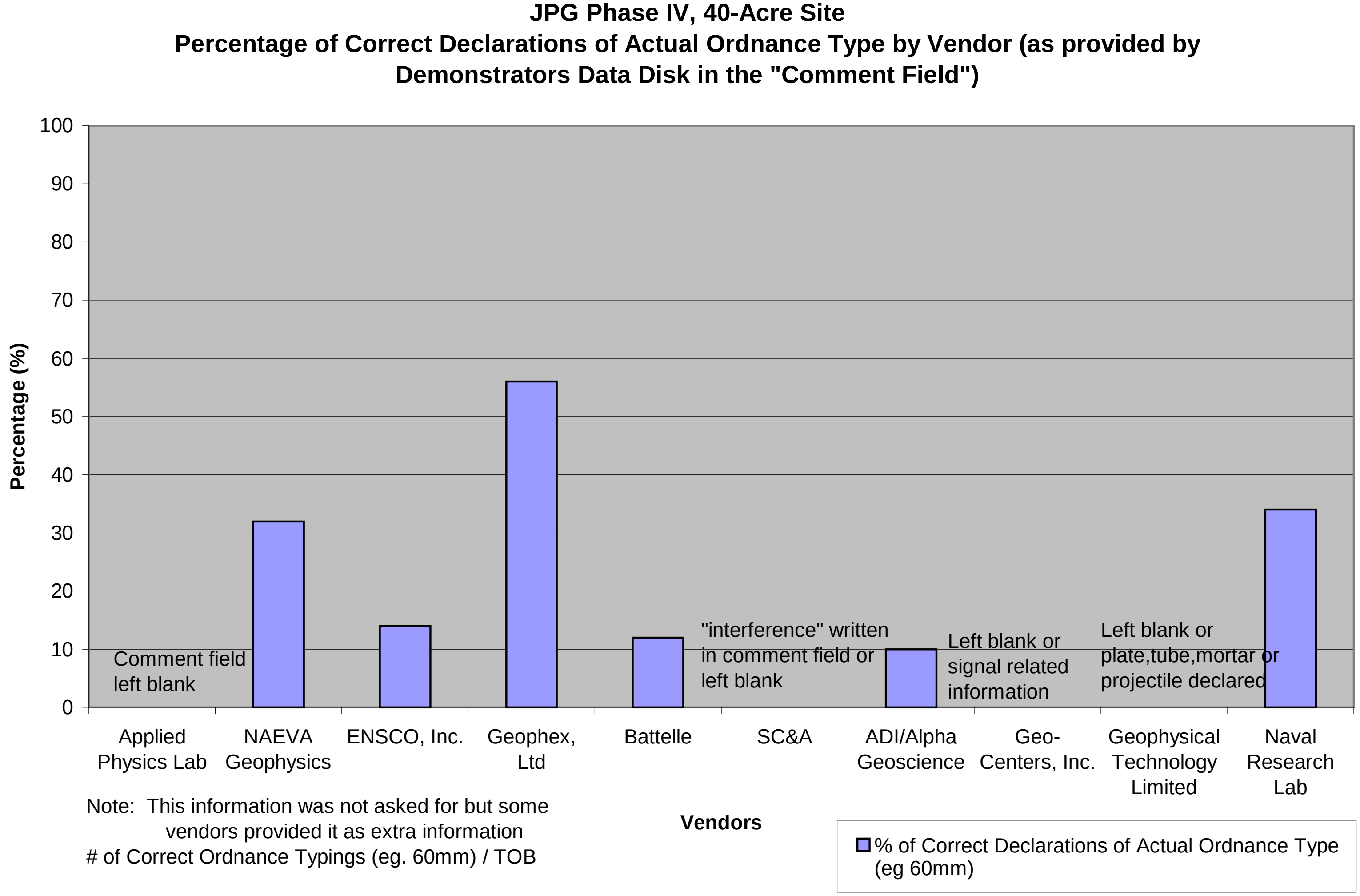


Table 4.1 - 5 , Distribution of Buried Ordnance & Vendor Declarations

Type of Target	Target #	APL	NAEVA	ENSCO	Geophex	Battelle	SC&A	ADI	Geo-Centers	GTL	NRL	TOTAL
20 mm HEI	5	0	1	1	1	1	0	0	0	0	0	4
	33	0	1	0	1	0	0	0	1	0	1	4
	72	0	0	1	1	0	0	1	0	0	0	3
	113	0	0	0	1	0	0	1	1	0	1	4
	155	0	0	0	1	1	0	0	1	0	1	4
	TOTAL	**0**	**2**	**2**	**5**	**2**	**0**	**2**	**3**	**0**	**3**	
57 mm (HE) wo/fuze, filler	20	0	0	1	0	1	0	0	1	0	1	4
	39	0	1	1	1	1	0	1	1	0	1	7
	68	0	1	0	0	0	1	0	1	0	1	4
	80	0	1	0	1	0	0	0	1	0	0	3
	118	1	0	0	0	0	0	0	1	0	1	3
	TOTAL	**1**	**3**	**2**	**2**	**2**	**1**	**1**	**5**	**0**	**4**	
60 mm Motar wo/fuze	17	0	0	1	1	1	0	1	1	0	1	6
	40	0	1	0	0	1	0	0	1	0	1	4
	61	0	1	0	1	0	0	1	1	0	1	5
	81	0	1	1	1	1	0	1	1	0	1	7
	146	0	0	1	1	1	0	0	0	0	0	3
	TOTAL	**0**	**3**	**3**	**4**	**4**	**0**	**3**	**4**	**0**	**4**	
76 mm (HEAT)	21	0	0	1	0	1	1	0	1	0	1	5
	46	0	1	0	1	1	1	1	1	0	1	7
	67	0	1	0	1	0	0	0	1	0	1	4
	88	0	0	0	1	1	0	1	1	0	1	5
	123	1	1	0	1	0	0	0	1	0	1	5
	TOTAL	**1**	**3**	**1**	**4**	**3**	**2**	**2**	**5**	**0**	**5**	
81 mm Mortar Practice wo/fuze	3	0	1	0	1	1	0	0	1	0	1	5
	47	0	1	0	1	1	0	0	1	0	1	5
	63	0	1	0	0	0	1	1	1	0	1	5
	89	0	0	0	1	0	0	0	1	0	1	3
	TOTAL	**0**	**3**	**0**	**3**	**2**	**1**	**1**	**4**	**0**	**4**	
81 mm Mortar (HE) wo/fuze	124	0	0	1	0	0	0	0	0	1	0	2
	TOTAL	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	
90 mm (AP) Practice	31	0	1	0	1	0	1	0	1	0	1	5
	79	0	1	0	1	0	1	0	1	1	0	5
	104	0	1	1	1	0	0	0	1	0	0	4
	138	0	0	1	1	1	0	1	1	1	1	7
	141	0	0	0	1	1	1	1	1	1	1	7
	TOTAL	**0**	**3**	**2**	**5**	**2**	**3**	**2**	**5**	**3**	**3**	
105 mm (APERS) wo/fuze	22	0	1	0	1	1	0	0	1	1	0	5
	52	1	1	0	1	1	1	0	1	0	1	7
	TOTAL	**1**	**2**	**0**	**2**	**2**	**1**	**0**	**2**	**1**	**1**	
105 mm (HEAT)	98	0	1	1	1	0	0	1	1	1	1	7
	137	1	1	1	0	1	0	0	1	1	1	7
	148	0	1	0	1	1	1	0	1	1	0	6
	TOTAL	**1**	**3**	**2**	**2**	**2**	**1**	**1**	**3**	**3**	**2**	
4.2" Mortar (HE) w/fuze	11	0	1	1	0	1	0	0	1	1	0	5
	57	0	0	0	1	0	1	1	1	1	0	5
	TOTAL	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**0**	
4.2" Mortar (HE) wo/fuze	99	0	1	0	1	1	1	1	1	0	0	6
	TOTAL	**0**	**1**	**0**	**1**	**1**	**1**	**1**	**1**	**0**	**0**	
4.2" Mortar (Illum.) wo/fuze	132	0	0	1	0	0	0	0	1	1	0	3
	152	0	1	0	1	1	1	0	1	0	1	6
	TOTAL	**0**	**1**	**1**	**1**	**1**	**1**	**0**	**2**	**1**	**1**	
152 mm Practice	27	0	1	0	1	0	1	0	1	0	1	5
	51	0	0	0	0	0	1	0	1	1	1	4
	92	1	1	1	0	1	0	0	0	0	0	4
	105	0	0	0	0	0	0	1	0	1	0	2
	114	0	1	1	0	0	0	0	0	0	0	2
	TOTAL	**1**	**3**	**2**	**1**	**1**	**2**	**1**	**2**	**2**	**2**	
155 mm (HE) w/lifting lug	56	0	1	0	0	0	1	1	1	1	1	6
	90	0	1	1	1	0	1	1	1	0	1	7
	117	0	1	0	0	0	0	0	1	0	1	3
	TOTAL	**0**	**3**	**1**	**1**	**0**	**2**	**2**	**3**	**1**	**3**	
155 mm (HE) w/fuze	8	0	1	0	1	0	1	1	0	1	1	6
	108	0	1	0	1	0	1	1	0	1	0	5
	TOTAL	**0**	**2**	**0**	**2**	**0**	**2**	**2**	**0**	**2**	**1**	

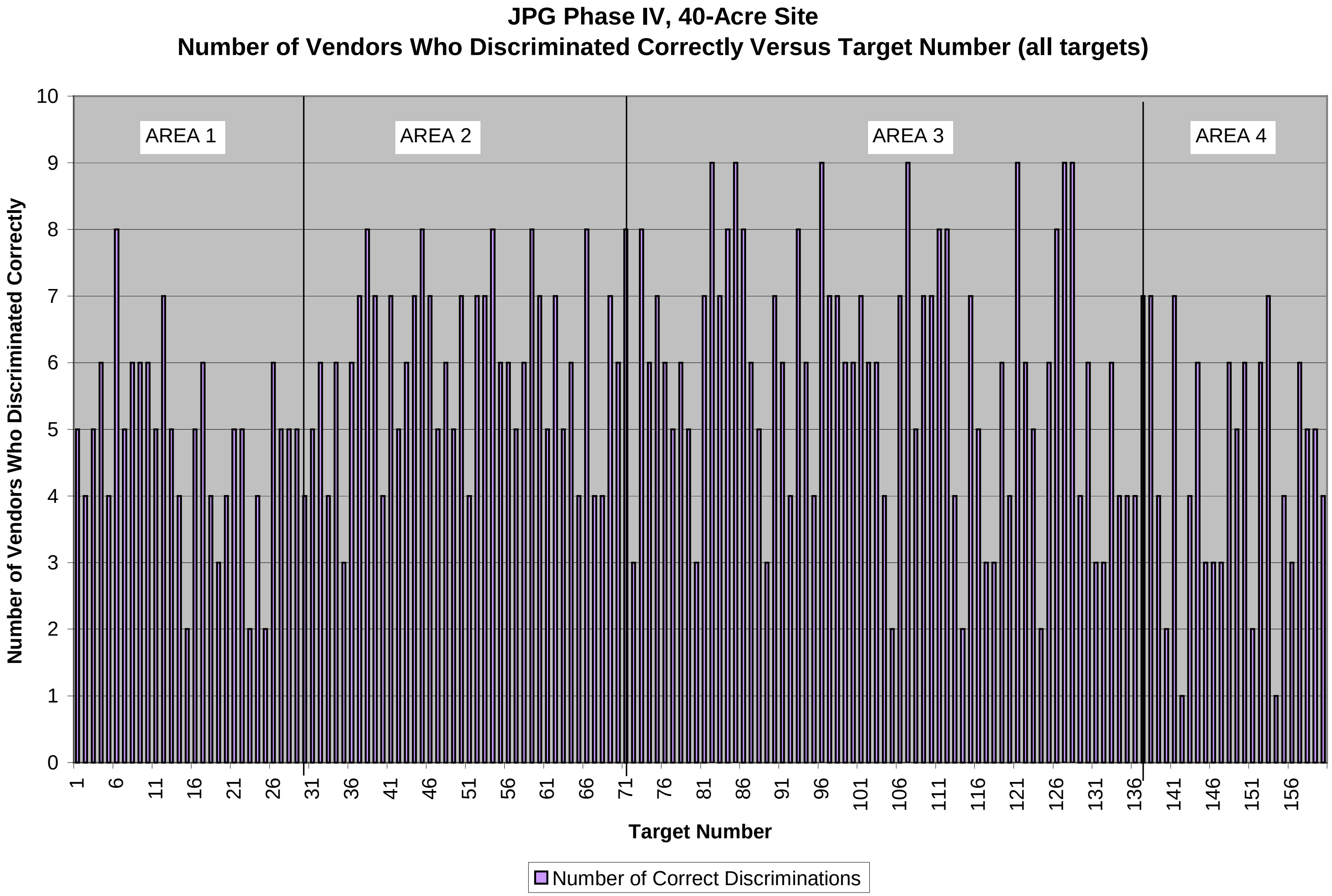
Graph 4.1 - 19 , Correct Declarations of Actual Ordnance Types



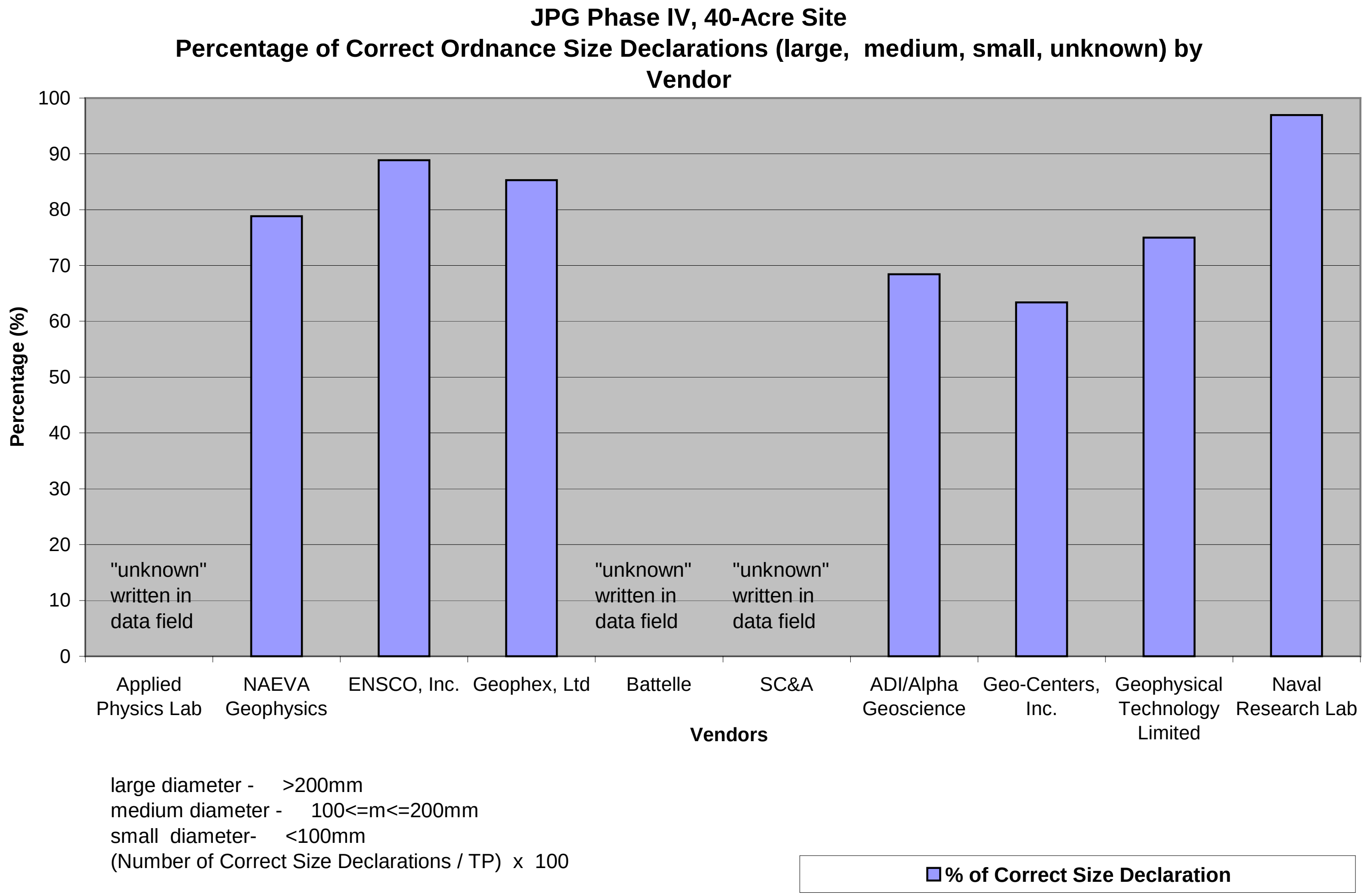
Note: This information was not asked for but some vendors provided it as extra information

# of Correct Ordnance Typings (eg. 60mm) / TOB

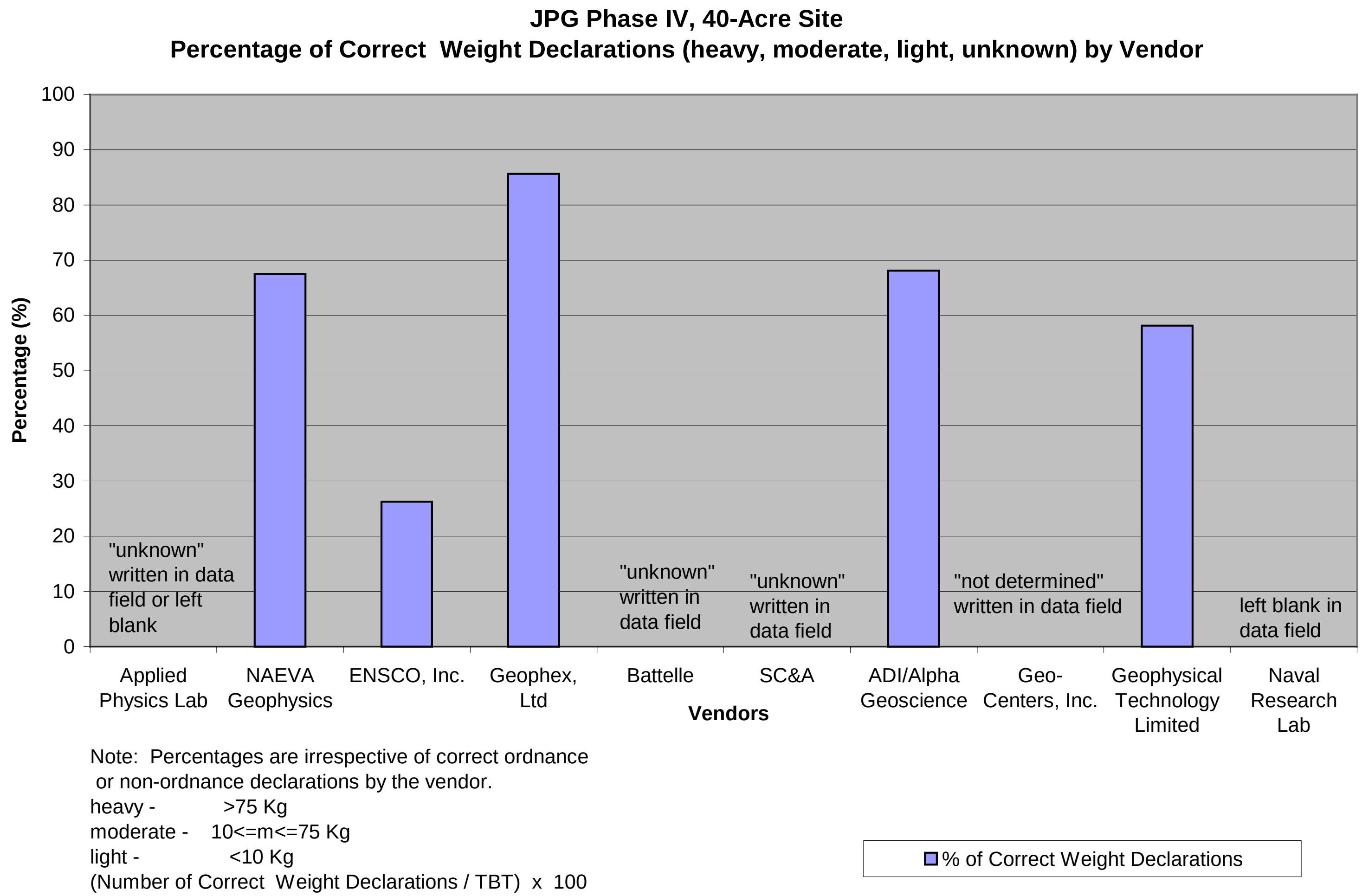
Graph 4.1 - 20 , Frequency of Correct Discrimination by Target Number



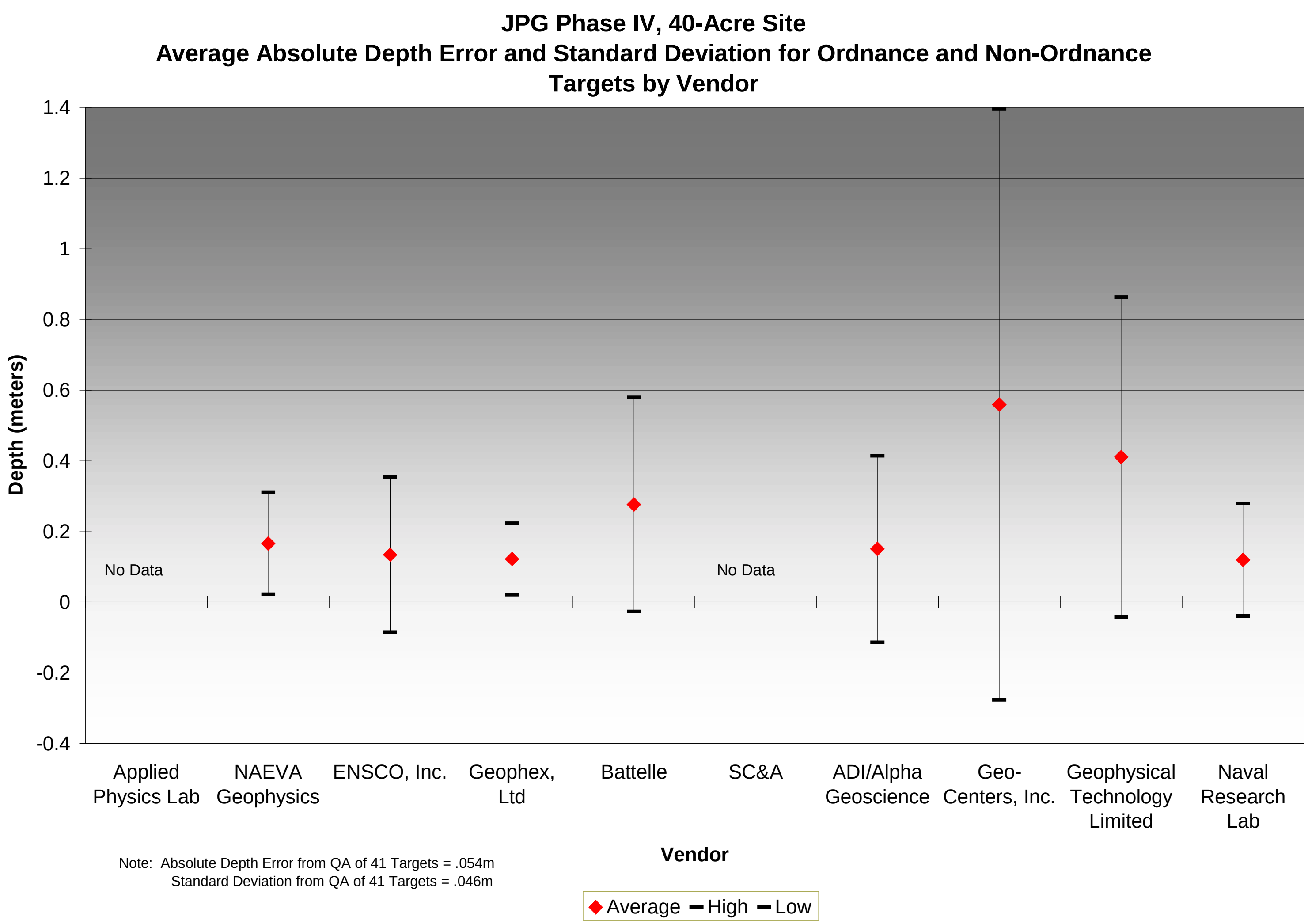
Graph 4.1 - 21 , Size



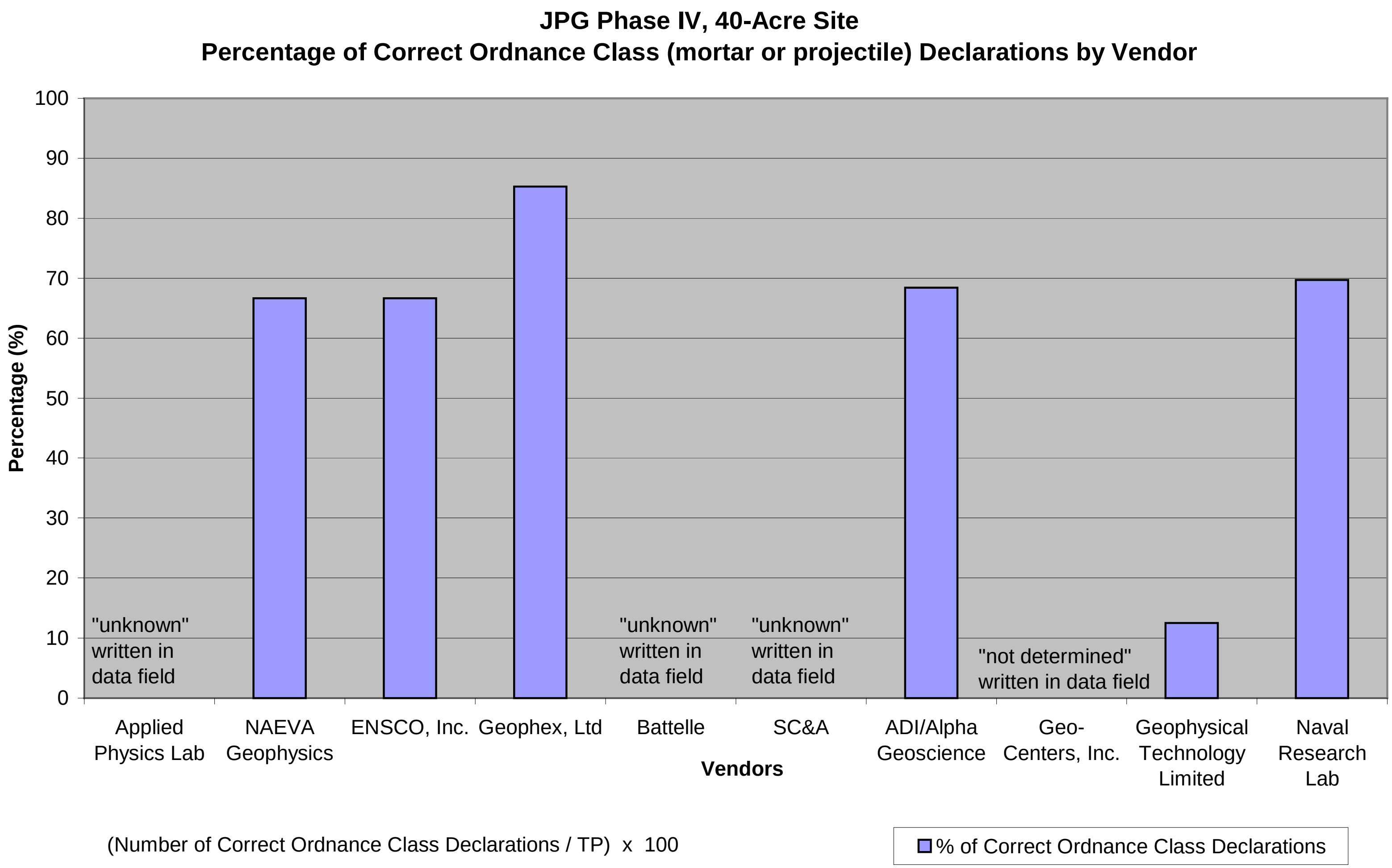
Graph 4.1 - 22 , Weight



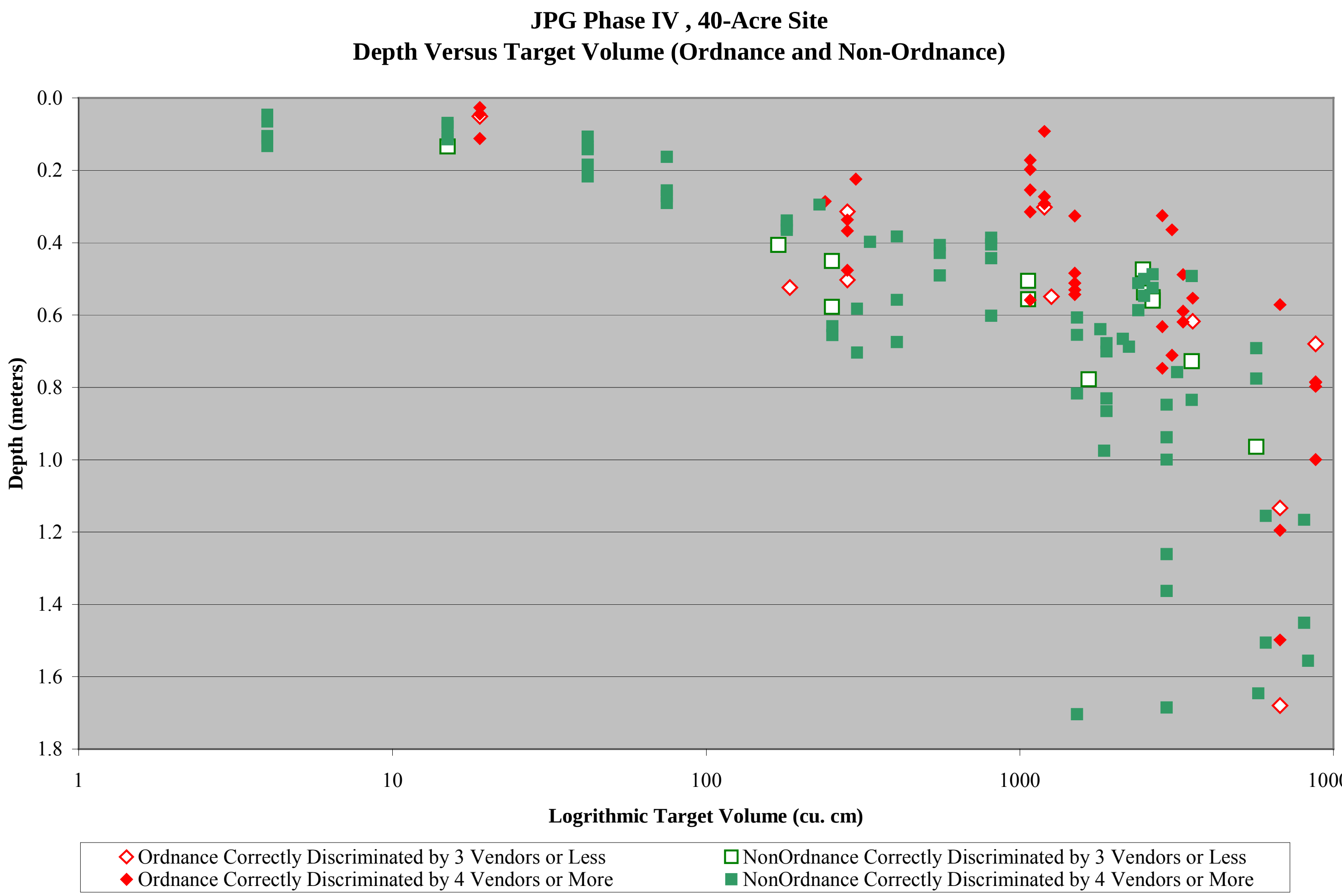
Graph 4.1 - 23 , Depth Error



Graph 4.1 - 24 , Class



Graph 4.1 - 25 , Volume



Note: Does not include 25 non-ordnance volumes

4.1.3 EXCAVATION

Concept Engineering Group (CEG) uncovered 13 ordnance and 17 non-ordnance targets whose positions were resurveyed to determine the effects of target placement settlement (further QA information can be found in the Appendix B). CEG demonstrated a field worthy and safe system of uncovering buried ordnance that minimizes disturbance of the UXO. It was noteworthy that as a result of this effort, it was determined that the burial process influenced original burial orientation. Therefore, azimuth and elevation could not be used in demonstrator evaluations

The following table shows the results CEGs'work:

TABLE 4.2 - 1 , Concept Engineering Excavation Time and Depth

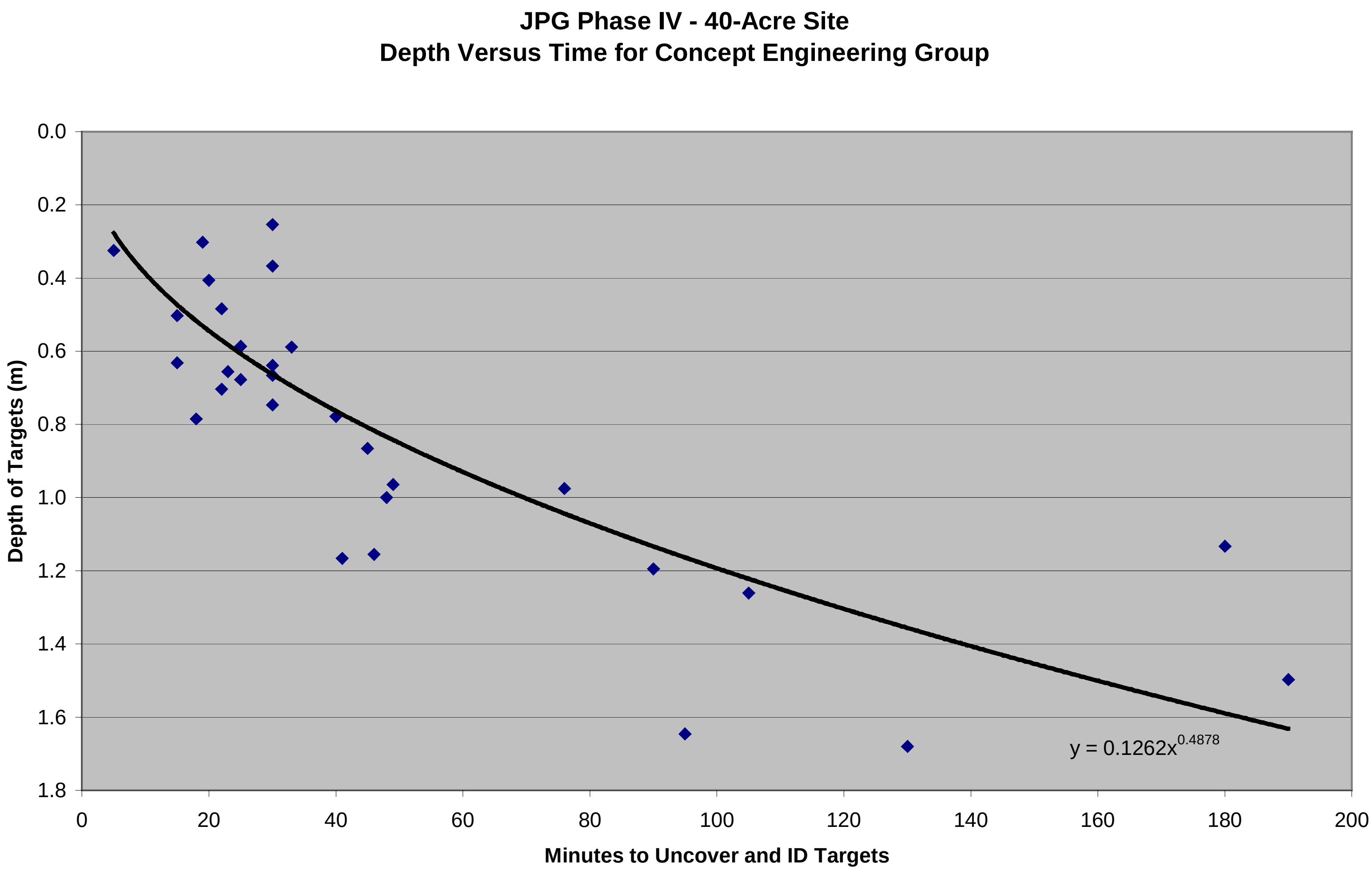
CONCEPT ENGINEERING GROUP	Average	Standard Deviation
Depth of Excavation (meters)	0.8	0.4
*Time (minutes – not including travel time)	44	41

* Exact target locations were marked with flags

Although time consuming compared to backhoes, certain situations arise where this system is necessary. Graph 4.2.1 shows the expected performance of the system by fitting data points to a power curve.

Statistics from past demonstrations show that the average excavation time for two of the three vendors (One remediator had a hard time navigating and locating their targets as evidenced by a 14.3 hour per hole rate. Their statistics are not included) at JPG Phase I was 56.4 minutes per hole and at JPG Phase II was 39.6 minutes per hole. CEG's performance in Phase II was 45 minutes per hole with a machine that weighed 34,000 lbs. and required several people to operate. For Phase IV the system weight was significantly less (it is positioned on a John Deer gator) and can be used by a single operator. It is difficult to compare systems because the traditional backhoes are designed to dig deep heavy targets. These systems have difficulties with small shallow targets that often drop into the overburden pile and require a second detection. Also, during Phase I and II, targets weren't marked with flags to help identify location.

Graph 4.2 - 1 , Depth of Target Versus Time to Uncover and Identify



4.2 ISSUES IN THE EVALUATION OF DEMONSTRATOR DATA

A JPG Phase IV Workshop was held at the Naval Explosive Ordnance Disposal Technology Division on February 9, 1999, where all the JPG participants were briefed on the initial assessment of performance based on publicly released ground truth data. During the workshop, an issue was raised concerning the treatment of “unknowns” as they were declared in the *TYPE* Field. When declarations are categorized or binned as TP or TN, a match is made between the ground truth and the demonstrator’s declaration. Responses that do not correspond to ordnance or non-ordnance declarations are binned to FN and FP indirectly because the ground truth basis of ordnance (50) targets and non-ordnance (110) targets are not reduced by the amount of unknowns that are really ordnance and non-ordnance.

There are four ways to deal with “unknown” declarations: (1) leave "unknowns" as unknowns, (2) retype "unknowns" as ordnance, (3) retype "unknowns" as non-ordnance, or (4) remove the “unknown” declared targets out of the baseline (the denominator for calculating TP, TN etc.). From a practical standpoint it could be argued that all “unknown” declared targets would require excavation since ordnance is assumed and it would be wise to err on the side of caution (argument #2). It can also be reasoned that on a real range an “unknown” would more likely be a piece of shrapnel or non-ordnance item. Probability would then tell us to declare the item as non-ordnance (argument #3). Unfortunate consequences may result at a real range if this argument is wrong.

Removal of the “unknown” declared targets from the baseline (argument #4), while sounding fair in principle has unfortunate side effects. The demonstrator could declare only those targets that he is relatively sure of and neglect the more difficult ones, thereby artificially inflating his system’s capabilities by his own baseline set.

The original purpose of the "unknown" category was to give the demonstrator a chance to declare "a dry hole" (a hole dug with nothing in it). Two of these holes were purposely put in the self-test area (80-acre site) with ground truth provided to the self-testers. Additionally, the “unknown” category left an opening for the demonstrator to use it in case of data drop out, corrupted data over a target, lack of sensor signal or target signature, or just an inability to discriminate the target in any meaningful way. In other words, a catch basin category for “no data” or “corrupt data”. Table 3.4-1 illustrates the point.

Table 4.2 – 2, Treatment of “Unknowns” in Demonstrator Data

Argument	TP	TN	FP	FN	TOB (total Ordnance buried)	TNOB (total non-ordnance buried)	Ordnance “unknowns”	Non-Ordnance “unknowns”	%TP	%TN
Leaving “unknowns” as unknown	33	48	62	17	50	110	5	14	**66**	**44**
Retyping “unknowns” as Ordnance	38	48	62	12	50	110	5	14	**76**	**44**
Retyping “unknowns” as Non-Ordnance	33	62	48	17	50	110	5	14	**66**	**56**
Removing “Unknowns” from the Ground Truth Baseline	33	48	62	17	45	96	5	14	**73**	**50**

As can be seen from the table above when retyping for ordnance (argument #2), TP increases from 66% to 76% and FN decreases by 5 targets --as it should. When retyping for non-ordnance (argument #3), TN increases from 44% to 56%. Removal of “unknowns” from the baseline shows an across the board increase in capability. This scenario in the governments’ opinion represents a measure of success that is not realistic. This is due to the fact that in order to evaluate demonstrator results on an even playing field, the ground truth must be the same for every demonstrator that had an opportunity to interrogate the target.

Lesson Learned - Although “unknown” is a perfectly acceptable response, it may be an indication that there is a problem with the demonstrator’s “discriminator”, his sensor, or his data collection process. The only way of knowing what “unknown” really means is for the demonstrator to clarify the term in his comment field. Future efforts should clarify the use of “unknown” more thoroughly.

Current sensors used to detect ordnance are not “ordnance detectors”, rather, they are anomaly detectors. They have no intrinsic capabilities within themselves to determine or judge the uniqueness of a target. The intent and purpose of Phase IV is to demonstrate the capability to discriminate ordnance from non-ordnance on a performance basis. How a demonstrator arrives at his decision, whether physics-based, probability-based, or just plain “guesstimation” is not the thrust of this report.

Several issues that were brought up by demonstrators were:

(1) Non-ordnance items that had aspect ratios (length to width) similar to ordnance,

Clarification: Of the 110 non-ordnance targets buried on the 40-acre site, only 11 had aspect ratios similar to ordnance (see Appendix B) and of those only two targets were incorrectly discriminated by four or less vendors.

(2) Vegetation such as tall grass that impeded sensor contact with the ground,

Clarification: The area was mowed several times during the demonstration period and scrub grass grew between cuttings. The targets had no objects over them, other than earth, and from an impact range point of view this would be considered maintained conditions.

(3) The process of burying targets that created “bathtub” effects which were depressions in the ground over the target,

Clarification: The issue of bathtubs is valid limitation for certain technologies i.e. GPR. However, after discounting bathtub areas from the baseline target set, the performance of the demonstrators did not improve. This issue is not statistically supported.

(4) Depth of target burials that may have been too deep for sensors to detect, and

Clarification: Target depths were chosen to reduce, but not eliminate, the possibility of “no detection’s”. Approximately five ordnance targets were buried at “challenging depths”.

(5) Anomalous signals too close to bona fide targets.

Clarification: Care was also taken to avoid noise sources in the vicinity of buried targets. A two-meter gradiometer sweep was performed around every burial location to eliminate sources of ferrous noise.

5.0 DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

5.1 DISCUSSION

In 1993, Congress mandated that the U.S. Army conduct a program at Jefferson Proving Ground (JPG), near Madison, Indiana, to demonstrate and evaluate systems and technologies that can be used to detect, identify, and remediate buried unexploded ordnance (UXO). Since that time, four separate and distinct Technology Demonstration Phases have been conducted. The subject matter of this report is JPG Phase IV, representing the culmination of a six year effort to demonstrate the utility of available technologies in supporting the needs of the DoD to clear UXO from active, inactive, closed, transferred, and transferring ranges. The DoD and the contractor communities have benefited from each progressive JPG Phase making the demonstrations, data analysis, and presentation of the results more useful to both the user and researcher. The JPG demonstrations provided DoD and the contractor community an opportunity to learn what types of technologies are most applicable to near term DoD UXO clearance needs. Further, the data collected provides insight into employing these technologies to reduce the cost and associated risks of clearance operations worldwide.

JPG Phases I, II, and III established a trend towards improvements in UXO detection as “mag and flag” approaches were replaced with transformed into more sophisticated approaches that employed multi-sensors, precise integrated navigation, and advanced data processing. Despite this progress, state-of-the-art UXO detection technology is plagued with high false alarm rates, attributed to the inability to distinguish UXO from man-made clutter. Assuming that anomalies can be detected, the ability to discriminate between UXO and non-UXO will greatly reduce costs associated with excavating non-ordnance.

Traditionally, *discrimination* is considered an integral function of *detection*. For UXO *detection*, this premise is valid if real “ordnance detectors” exist. However, the instruments used to survey for UXO are “anomaly detectors”. If environmental changes or noise sources (attributed to geology, range debris, or clutter) are greater than changes attributable to UXO targets, the UXO targets will <u>not</u> be *detected*. It is imperative to note that if UXO is not *detected*, there can be no *discrimination*. Hence, the problem is therefore two fold: (1) UXO not *detected* remains a hazard, and (2) excessive false alarm rates (FAR) for UXO that encumbers high *detection* rates increase the cost of UXO clearance operations. For JPG Phase IV, only the later problem was addressed by treating *discriminatio*n as a separate activity driven largely by the disproportionately high FAR for UXO. JPG Phase IV serves to emphasize the current needs and developments in UXO *discrimination* technology, by functionally de-coupling it from UXO *detection.*

In JPG Phase IV, the JPG test site was specifically modified for the evaluation of UXO *discrimination* technology, where vendors were allowed to interrogate identified anomaly locations and gather dense data sets in an effort to assess their capability to discriminate ordnance and non-ordnance clutter. As such, the JPG Phase IV performance goals were set in place as follows:

- 95% effective discrimination of UXO targets that range in size from 20 mm projectiles to 155mm projectiles, and
- 75% effective discrimination of comparable-sized non-UXO (clutter) targets,

Beyond the emphasis on technology demonstration, the JPG Phase IV provides the UXO detection and clearance community with substantial data to evaluate the utility of various technologies as well as the resources needed to address some of the issues identified in earlier JPG phases. Specifically, a Science and Technology (S&T) component was added to JPG Phase IV to include:

a. JPG Site characterization. The U.S. Army Waterways Experiment Station (WES) conducted a site characterization to gather site specific data, which allows for the evaluation of variations in performance due to environmental, geological, geo-technical and geophysical factors. Additional work is still necessary to fully correlate this data set with sensor data.

b. Raw Sensor Data. Demonstrators provided raw sensor data, which was collected in a standardized format. After the demonstration effort was complete, the demonstrators were provided the ground truth data to enhance their learning experience. Additionally, the raw sensor data sets and the ground truth data set are readily available on the UXOCOE website (www.denix.osd.mil/UXOCOE). It is intended that this data be used by the UXO Clearance community to enhance signal-processing efforts.

c. Self-Test Area. Prior to the Phase IV "blind test" demonstration, demonstrators were allowed to collect data in a self-test area, which had representative buried targets. Information about the targets, including location, depth, type, class, orientation, was provided to the demonstrators. The self-test area was constructed to provide vendors with an opportunity to "tune" their systems as a precursor to the blind tests. No data or information was collected by the government to determine the benefit to the demonstrators of this self-test site. In after-action discussions held with the demonstrators, some found the self-test area of little value while others found it beneficial. However, all demonstrators found great value in the opportunity to take measurements of ordnance and non-ordnance samples above ground.

d. Peer Review of Results. A workshop was held for S&T representatives from all five of the DoD UXO clearance mission areas to discuss the JPG Phase IV results, recommend methods for improving the data analysis, make general suggestions for enhancing future UXO clearance experiments, and discuss potential implication of the findings. Most of these recommendations were included in the final report, such as: 1) including a chart for depth versus target volume for ordnance and non-ordnance (graph 4.1-25); 2) placing error bars on the depth error data (graph 4.1-23); 3) placing probability curves on the "optimal graph" (i.e. graph 4.1-1); and 4) changing the size

(graph 4.1-21) and class graph (graph 4.1-24) denominators to true positives (TP) rather than total ordnance buried (TOB).

Additionally, in determining the course for the Phase IV effort, the recommendations from Phase III were visited. As such, it is appropriate to revisit the list of recommendations from Phase III after completing Phase IV. Some of these earlier recommendations remain unaddressed.

- **Phase III Recommendation: Incorporate other UXO scenarios as advisable**. For JPG IV, other UXO scenarios were not incorporated. If fact, the UXO scenario employed was more limited to those scenarios depicted in JPG III. Discrimination was the defacto “scenario” for Phase IV. Discrimination remains a subject of controversy within the UXO community. In the detection role, GPR, IR, and/or other costly, high resolution imaging technologies have not shown promising results given the conditions at JPG. However, there is evidence that some sensor suites may be better suited for discrimination, taking away the responsibility of detection and location. The results show that, currently, the traditional electro-magnetic sensors and processing algorithms are not only better suited for detection but that they are also better suited for discrimination at this site.

- **Phase III Recommendation: Encourage system approaches to UXO detection and excavation**. During JPG IV, system approaches for excavation have not been addressed. However, the bar set in the Phase IV goals for discrimination has encouraged system approaches for UXO detection and funding provided to demonstrators to support these goals. As the UXO detection challenges have grown with each successive JPG Phase, so too have the system challenges. Hence, it is not surprising that system approaches have been utilized more and more with succeeding JPG Phases and that these system approaches have been driven more by private industry than government initiatives. Also, sensor manufacturers, academia, software companies, and cleanup industries are forming partnerships attempting to find the most optimal mix of resources.

- **Phase III Recommendation: Set a consistent standard for reporting non-ordnance so that demonstrator’s false alarm metrics and discrimination (typing) capabilities are better determined.** This issue will not be resolved as a result of JPG Phase IV or any future JPG type technology demonstrations. This issue can only be resolved at a DoD wide policy level. The problem arises with the definition of *non-ordnance*. For example, is the tail-fin section of a fired 81mm mortar considered ordnance? From an explosive safety standpoint most likely not, from an EOD standpoint it is ordnance debris, from a public perspective, leaving ordnance debris out of the clearance standard presents serious public perception issues. When ranges are “clean”, an assumption is made concerning the risk level and human intervention that will be applied to that range. For blind test demonstration purposes the variable of “non-ordnance” can be controlled by the test planner, however, real ranges will blur that definition because variables cannot be assumed and therefore cannot be controlled.

- **Phase III Recommendation: Re-examine the ordnance size standards to determine if they should be changed, or if another measure, such as target volume, might be more useful**. During JPG IV, data was collected and results presented on target volume as a function of depth and target diameter as a function of depth. Although no appreciable difference was observed between the two at this time, these results are not intended to be conclusive.

- **Phase III Recommendation: Eliminate the need for demonstrators to classify ordnance as mortar, bomb, etc., until such time as their ordnance typing capabilities have developed**. JPG Phase IV has provided data at some level of confidence to show that a burgeoning capability to type ordnance exists and generic ordnance classifications should be included in any further tests. In interpreting this capability, one should remember that JPG IV target set was limited to a select set of ordnance types ranging in size from 20mm to 155mm rounds.

- **Phase III Recommendation: Characterize "noise sources" (e.g. shrapnel) on live ranges so that debris conditions are more realistic.** Here again, this effort is larger than the scope of the JPG technology demonstrations. For JPG IV demonstration purposes, the definition of non-ordnance was "…anything that is not a completely intact, inerted, ordnance casing". Further, the government emplaced these non-ordnance targets. No provisions were made to deal with real-world risk issues associated with "anomalous readings" such as ordnance debris (non-intact ordnance to include, fin assemblies, expired rocket motors, bomb base plates, etc.), white phosphorous debris, fuze components, spotting charges, etc. These are all hazardous items that don't fit easily into the "containment" categories of ordnance and non-ordnance. **Noise sources on live ranges are potentially infinite. The issue of noise source characterization centers around defining a representative sample for the infinite possibilities.** Little is known of the "clutter signature" environment on ranges, other than the UXO density should diminish as one travels away from the impact zone. From a point detection sensor and economic perspective, thresholds must be established to indicate the point of futility where clutter signature continues to drive the FAR beyond bound. In these cases a range cleanup will, to some level of certainty, result in a "strip mining operation" or denial of human access until a significant "technology push" arrives to make clean up operations feasible. Such characterization also will help define the relationship between clutter signatures and UXO hazard signatures, if the UXO signatures are characterized as well.

5.2 CONCLUSIONS

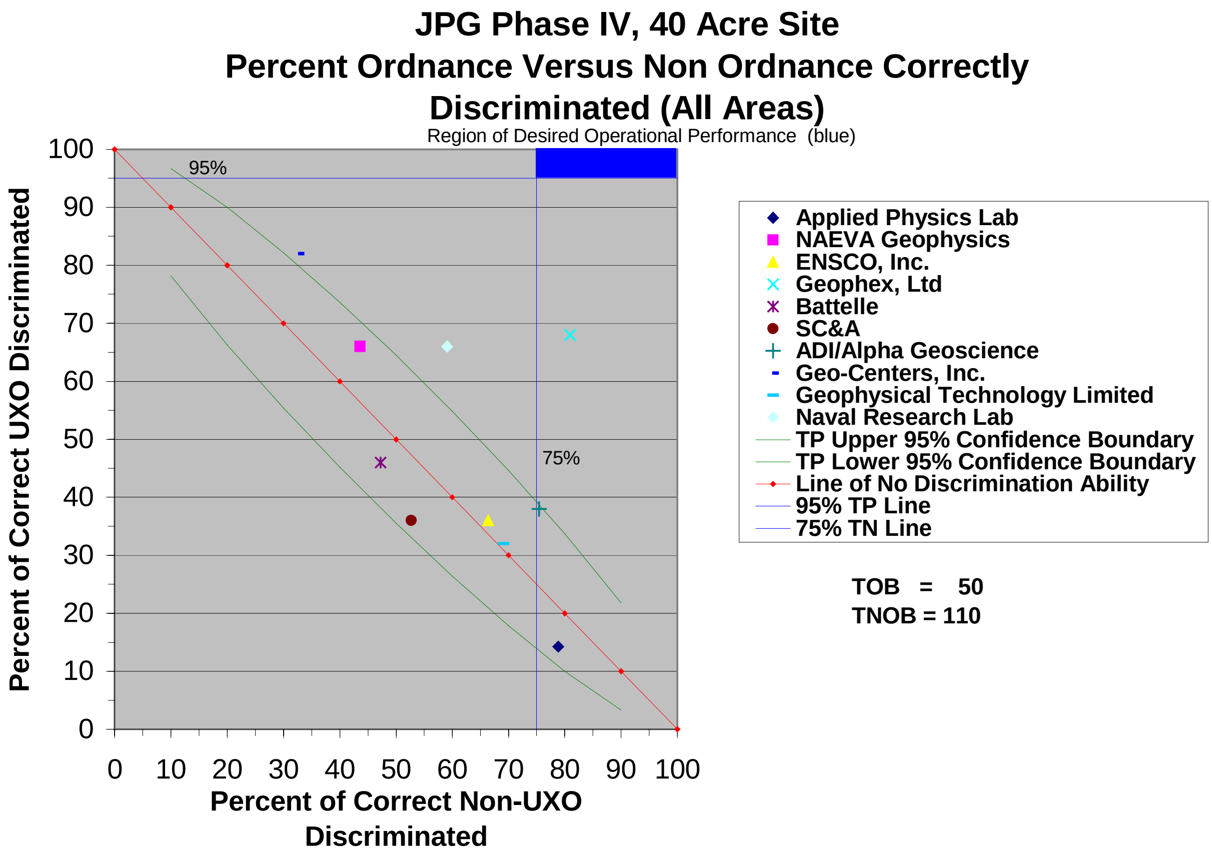
Demonstrators used a variety of sensors and/or enhanced data analysis methods in their technical approaches to address the goals of JPG IV. Their approach and *discrimination* strategy was influenced by economics and included decisions regarding sensor technology, numbers of sensors, operational platforms used, sensor sampling thresholds, sampling procedures, data platforms, algorithm development, data processing, data analysis, choice of test personnel, and quality control.

Regardless of their approach, the assessment of JPG Phase IV demonstrator performance was based solely on the ability to distinguish between full, intact, inerted, non-degaussed, hand emplaced inert ordnance and man-made, ferrous targets/hand emplaced debris. Clutter items (non-ordnance) were manufactured and are not known to be representative of debris on a "real" range. Rather, clutter items were fabricated to challenge the ability of demonstrators to determine the difference between ordnance and non-ordnance (10% of the clutter items had aspect ratios similar to ordnance). This report does not attempt to include the demonstrator's hidden decision making processes, to evaluate raw sensor data, or to assess data collection methodologies. The results from JPG Phase IV should be viewed as a single data point and are not intended to set future range clearance performance specifications; nor is it a good predictor of performance at other locations. Further, employing the demonstrated systems for UXO *detection* surveys may be impractical, as JPG Phase IV assessed UXO *discrimination* abilities at identified, " known" target locations.

The JPG Phase IV performance goals were set in place as follows: (1) 95% effective discrimination of UXO targets that range in size from 20 mm projectiles to 155mm projectiles, and (2) 75% effective discrimination of comparable-sized non-UXO (clutter) targets. Although no demonstrator was able to attain this level of performance, several demonstrators showed a modest capability to discriminate ordnance from non-ordnance, given the removal of the *detection* burden. Five of the ten demonstrators showed a capability to discriminate ordnance and non-ordnance that was better than the chance probability of 50%, as shown in Graph 5-1. A single graph cannot show the complete results and complexities from JPG Phase IV, however, Graph 5-1 is a general indicator comparing TP versus TN for all areas. The shaded area in the top right corner of the graph represents the performance goal and the area bounded by the green curve parameters exceeds the 95% confidence boundary.

Graph 5 – 1. TP versus TN (All Areas)

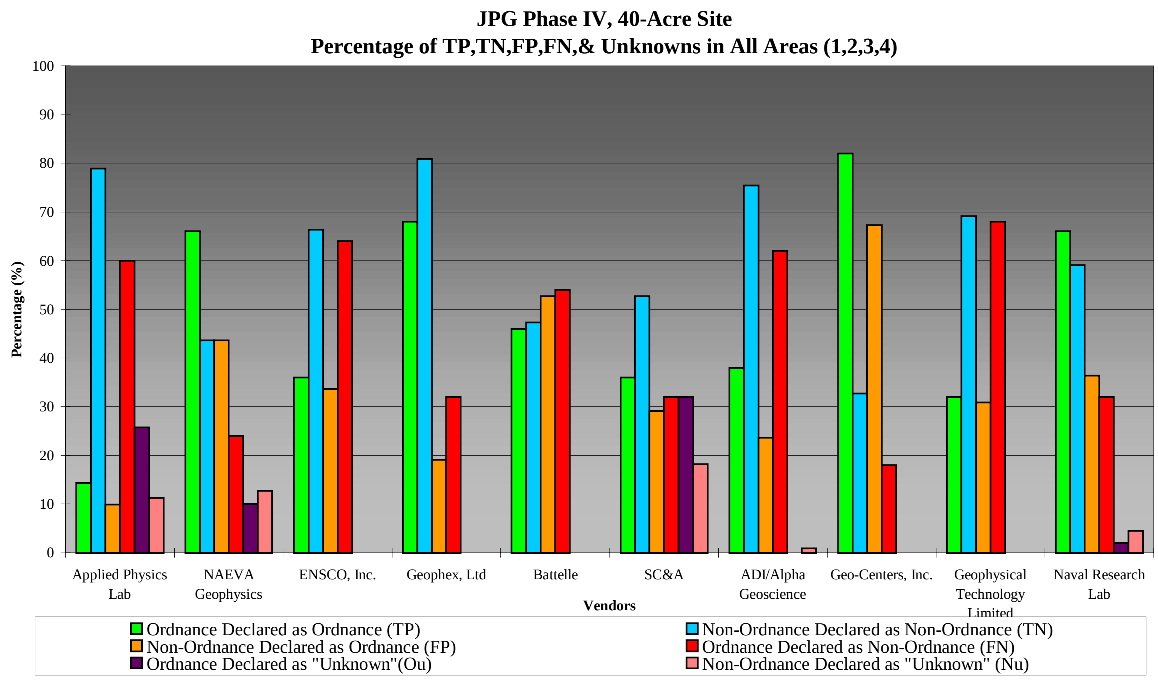
*Note: Graph 5–1 is identical to Graph 4.1–1 herein



As can be seen in Graph 5-2, Geophex, and the Naval Research Laboratory showed some capability to correctly distinguish the inert ordnance from the artificial clutter. Common to all these vendors were their multi-sensor approach, employing magnetometry and electromagnetic induction enhanced by advanced signal processing.

Graph 5 - 2 . TP, TN, TP, FP (All Areas)

*Note: Graph 5–2 is identical to Graph 4.1–6 herein



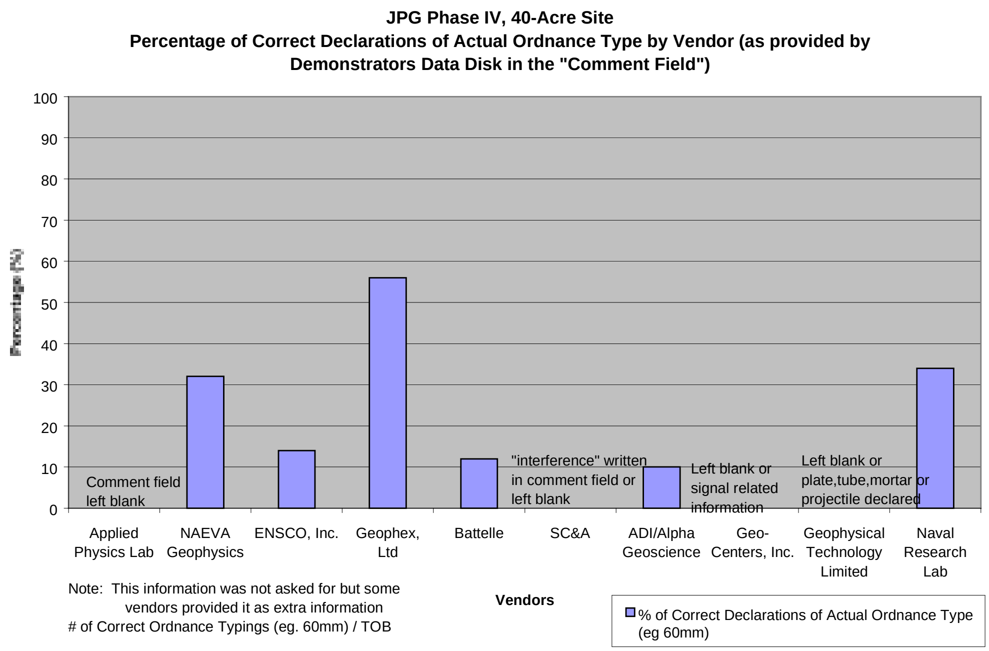
APL - TOB=35, TNOB=71, Ou=9, Nu=8, not surveyed=54
NAEVA - TOB=50, TNOB=110, Ou=5, Nu=14
SC&A - TOB=50, TNOB=110, ? u=16, Nu=20
ADI - TOB=50, TNOB=110, Ou=0, Nu=1
NRL - TOB=50, TNOB=110, Ou=1, Nu=5
All Others - TOB=50, TNOB=110, Ou=0, Nu=0

%TP = (Correct Ordnance Declarations / TOB) x 100
%TN = (Correct Non-Ordnance Declarations / TNOB) x 100
%FP = (Non-Ordnance Declared as Ordnance / TNOB) x 100
%Ou = (Ordnance Declared as Unknown / TOB) x 100
%Nu = (Non-Ordnance Declared as Unknown / TNOB) x 100
%FN = (Ordnance Declared as Non-Ordnance / TOB) x 100

Graph 5-3 shows the ability of some demonstrators to, not only distinguish ordnance from non-ordnance, but to declare the type of ordnance detected. Geophex, NAEVA Geophysics, and the Naval Research Laboratory demonstrated an ability to recognize the signatures of specific types of ordnance in the JPG IV target set. Geophex was able to correctly determine the ordnance item (e.g. 60mm mortar, 20mm projectile, etc.) over 55% of the time. The Naval Research Lab and NAEVA Geophysics were able to correctly identify the kind of ordnance over 30% of the time. This is a significant increase in discrimination capability not seen in previous JPG demonstration phases. These three vendors used the multi-sensor approach, employing magnetometry and electromagnetic induction, enhanced by advanced signal processing.

Graph 5 – 3. Correct Declarations of Actual Ordnance Types

*Note: Graph 5–3 is identical to Graph 4.1 - 19 herein



Although excavator technology demonstrations were not the focus of JPG IV, the Concept Engineering Group (CEG) used their air spade to uncover and re-survey the positions of a limited number of ordnance and non-ordnance targets to assess the effects of target placement settlement.

CEG's average target depth of excavation was .82 meters with a corresponding excavation rate of 1.0 m/hr. On the surface, this excavation rate compares unfavorably with their previous Phase II performance of 1.00 meter excavation depth at a rate of 1.3 m/hr. However, the lose in excavation rate may be attributed to a system tradeoff as the current system weighs 80% less and requires fewer personnel to operate than the system used in Phase II.

5.3 RECOMMEDATIONS

There are inherent limitations on the detection capability of geophysical systems caused by the size and depth of burial of UXO (a given UXO may be too small and/or too deep to produce a detectable anomaly signature); these limitations exist regardless of the geological and clutter backgrounds. The geological background further decreases UXO detectability by attenuating signatures, reducing physical property contrasts, and providing sources of localized anomalies. The cultural background or clutter decreases the reliability of UXO detection due to interference signals and false alarm anomalies caused by surface and buried cultural features. Regardless of the background, *detection* of UXO must ultimately be accomplished to effectively minimize the risk of UXO hazards. *Discriminatio*n serves to reduce the costs associated with

excavating non-ordnance and to reduce the risk and cost of excavating ordnance by knowing the ordnance type.

The assessment of a demonstrator's performance during JPG Phase IV was based on their ability to distinguish between the intact, non-degaussed, inert ordnance and the emplaced "clutter". Clutter items (non-ordnance) were manufactured and were not representative of debris from a range. Manufactured clutter bounded the non-ordnance sample space and established an experimental basis for distinguishing ordnance from "not ordnance". Yet, it is evident from these limited UXO *discrimination* trials, that new and continued developments in sensor technologies and processing are needed to meet the discrimination objectives.

Future efforts regarding UXO *discrimination* should focus on programs to increase the true positive (TP) and true negative (TN) rates and to further characterize "noise" sources on real ranges. True identifications (TP and TN) decrease both the risk and cost of UXO site remediation. It is highly desired to obtain technologies that have increased ability to discriminate ordnance from non-ordnance, as well as to identify what type ordnance item is buried. The key to more efficient UXO remediation lies in the products that benefit from a partnership between industry and government which seeks to aggressively develop cost effective remediation technology to replace antiquated, currently fielded tools and practices. Over the course of the four demonstration phases at JPG, advances have been made in UXO detection, discrimination, and identification capability as a result of these partnering efforts.

The government needs to continue its involvement in the evaluation of UXO detection and discrimination technologies until the field is mature and profitable enough for the market place to support its evolutionary development. It is recommended that economic incentives be incorporated in remediation contracts to encourage the continued development and field evaluation of *discrimination* technologies.

The most promising technology approaches employed in the JPG demonstration efforts, may or may not be effective at other site locations. As such, the results of JPG should not universally be applied. Rather, blind tests, such as those employed in the JPG demonstrations, can effectively assess potential technologies for any given site. Blind testing can level the playing field and distinguish performance ability from chance. Accordingly, blind test sites established at other unique locations, can expand the knowledge base of external environmental influences on performance.

Target signature data sets are available for the sensors employed during the JPG Phase IV technology demonstration effort and DARPA-sponsored test sites. Additionally, there is a need for comprehensive, real world "clutter" and "ordnance" data sets, for use by those who wish to study the problem to include technology developers. Data sets, such as these, would reduce developers overhead costs and allow them to study discrimination with realistic targets. Government established sites, such as JPG, should be made available to those who wish to run field trials.

It is strongly recommended that government sponsored UXO technology demonstrations be continued. As a stand-alone asset, the JPG controlled test site is a unique national resource

for assessing UXO technologies. The financial and scientific investments at JPG have been considerable since 1994 and have set a benchmark for performance in the UXO cleanup community by: (1) serving to document the capabilities and limitations of sensor systems as they are developed, (2) providing a method for current UXO detection system vendors to assess their probability of detection, false-alarm rates, and ability to discriminate ordnance from non-ordnance, (3) highlighting the strengths of some technology approaches and the weaknesses of others, and (4) providing valuable insights into the complicated issues surrounding UXO detection and cleanup.

Consideration should also be given to designating other DoD test areas (where the ground truth data is controlled) for technology demonstration efforts to provide a broader sample of data sets influenced by geological, vegetative, and other environmentally induced variations. As noted earlier, 75% of UXO cleanup costs are attributed to the removal of non-ordnance items. By harnessing the collective efforts of the government, industry and academia, and through the continuation of DoD sponsored UXO technology demonstrations, decision-makers are provided with better knowledge and an appreciation of UXO detection and discrimination capabilities and the associated expected return for their cleanup dollar investment.

APPENDIX A

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(continued)

Applied Physics Laboratory

demonstrator	target	northing	Easting	depth	type	confidence	weight	size	azimuth	declination	class	comments	Decay Const.	Amplitude	target	target	type
APL = 019(?)					UXO=1	1=hi 5=low											UXO=1
	1	4309722.7	641501.696	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		1	54	1
	2	4309714.7	641491.126	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		2	77	1
	3	4309723.5	641489.958	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		3	123	1
	4	4309712.5	641508.142	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		4	52	2
	5	4309699.3	641487.295	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		5	59	2
	6	4309707.5	641478.926	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		6	92	2
	7	4309695.3	641497.248	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		7	95	2
	8	4309690	641519.415	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		8	118	2
	9	4309676.4	641524.959	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		9	119	2
	10	4309671.3	641533.847	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		10	125	2
	11	4309711.9	641524.55	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		11	126	2
	12	4309704.6	641533.326	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		12	137	2
	13	4309684.8	641503.19	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		13	40	3
	14	4309700	641516.888	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		14	42	3
	15	4309698.2	641541.133	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		15	44	3
	16	4309685.3	641538.475	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		16	46	3
	17	4309666.5	641517.38	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		17	47	3
	18	4309662.1	641508.739	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		18	48	3
	19	4309660.2	641525.295	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		19	49	3
	20	4309656	641500.356	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		20	56	3
	21	4309647.8	641513.14	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		21	57	3
	22	4309648.9	641528.649	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		22	61	3
	23	4309640.8	641533.11	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		23	62	3
	24	4309633.7	641524.656	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		24	63	3
	25	4309647.9	641494.907	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		25	64	3
	26	4309636.7	641511.679	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		26	65	3
	27	4309637.3	641494.332	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		27	67	3
	28	4309648.3	641480.078	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		28	68	3
	29	4309639.6	641477.015	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		29	69	3
	30	4309631.1	641481.157	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		30	35	4
	31	4309543.5	641641.287	unknown	5	1		unknown	unknown	unknown	unknown		20.2	16070.5	31	36	4
	32	4309539.6	641651.138	unknown	5	1		unknown	unknown	unknown	unknown		40.4	137.0	32	41	4
	33	4309536.1	641637.053	unknown	5	1		unknown	unknown	unknown	unknown		60.0	23.6	33	43	4
	34	4309542.8	641627.659	unknown	5	2		unknown	unknown	unknown	unknown		41.2	12.3	34	45	4
	35	4309533.3	641646.42	unknown	4	2		unknown	unknown	unknown	unknown		9.3	1060.7	35	50	4
	36	4309531.1	641627.886	unknown	4	4		unknown	unknown	unknown	unknown		16.7	773.2	36	53	4
	37	4309527.8	641639.373	unknown	5	1		unknown	unknown	unknown	unknown		54.5	62.0	37	55	4
	38	4309524.9	641621.874	unknown	5	2		unknown	unknown	unknown	unknown		42.1	65.4	38	58	4
	39	4309517.6	641625.273	unknown	5	2		unknown	unknown	unknown	unknown		17.8	65.8	39	60	4
	40	4309531.6	641607.383	unknown	3	3		unknown	unknown	unknown	unknown		3.0	818.5	40	66	4
	41	4309525.7	641610.299	unknown	4	2		unknown	unknown	unknown	unknown		10.1	263.3	41	70	4
	42	4309518.2	641604.885	unknown	3	3		unknown	unknown	unknown	unknown		8.2	417.2	42	71	4
	43	4309512.9	641612.771	unknown	4	2		unknown	unknown	unknown	unknown		11.7	101.0	43	73	4
	44	4309506.9	641625.358	unknown	3	4		unknown	unknown	unknown	unknown		12.1	734.0	44	75	4
	45	4309513.3	641635.27	unknown	4	2		unknown	unknown	unknown	unknown		10.6	498.9	45	76	4
	46	4309520.3	641636.633	unknown	3	3		unknown	unknown	unknown	unknown		7.4	4478.1	46	78	4
	47	4309519	641646.014	unknown	3	3		unknown	unknown	unknown	unknown		5.0	245.6	47	79	4
	48	4309511.7	641648.615	unknown	3	2		unknown	unknown	unknown	unknown		9.0	2692.4	48	82	4

	49	4309505.2	641641.096	unknown	3	2		unknown	unknown	unknown	unknown		9.1	1415.3	49	83	4
	50	4309500.5	641633.492	unknown	4	2		unknown	unknown	unknown	unknown		11.7	36.4	50	84	4
	51	4309492	641640.43	unknown	5	1		unknown	unknown	unknown	unknown		73.2	15.7	51	86	4
	52	4309493.9	641651.481	unknown	2	1		unknown	unknown	unknown	unknown		29.9	3123.0	52	87	4
	53	4309502.1	641654.457	unknown	4	2		unknown	unknown	unknown	unknown		9.8	101.2	53	89	4
	54	4309488.6	641658.991	unknown	1	2		unknown	unknown	unknown	unknown		13.8	40.4	54	90	4
	55	4309481.4	641663.296	unknown	4	2		unknown	unknown	unknown	unknown		20.0	542.0	55	91	4
	56	4309478.6	641677.073	unknown	3	2		unknown	unknown	unknown	unknown		22.3	787.2	56	93	4
	57	4309487.5	641674.043	unknown	3	3		unknown	unknown	unknown	unknown		5.9	6117.5	57	94	4
	58	4309486	641684.146	unknown	4	2		unknown	unknown	unknown	unknown		12.1	67.7	58	96	4
	59	4309492	641680.965	unknown	2	2		unknown	unknown	unknown	unknown		12.9	784.3	59	97	4
	60	4309497.8	641670.668	unknown	4	2		unknown	unknown	unknown	unknown		15.7	290.8	60	98	4
	61	4309511.2	641664.395	unknown	3	3		unknown	unknown	unknown	unknown		7.6	58.9	61	99	4
	62	4309518	641669.516	unknown	3	3		unknown	unknown	unknown	unknown		8.3	161.2	62	100	4
	63	4309526.9	641666.139	unknown	3	3		unknown	unknown	unknown	unknown		3.9	8288.3	63	101	4
	64	4309538.9	641668.482	unknown	3	3		unknown	unknown	unknown	unknown		7.7	1942.2	64	105	4
	65	4309547.1	641676.587	unknown	3	3		unknown	unknown	unknown	unknown		7.1	1259.9	65	107	4
	66	4309543.2	641685.242	unknown	4	2		unknown	unknown	unknown	unknown		24.9	46.3	66	109	4
	67	4309537.1	641680.903	unknown	3	3		unknown	unknown	unknown	unknown		5.7	1578.8	67	110	4
	68	4309530.7	641686.627	unknown	3	3		unknown	unknown	unknown	unknown		6.9	122.4	68	111	4
	69	4309529.7	641675.592	unknown	3	3		unknown	unknown	unknown	unknown		6.9	148.5	69	112	4
	70	4309521.6	641686.129	unknown	4	2		unknown	unknown	unknown	unknown		12.1	607.7	70	113	4
	71	4309511.3	641685.851	unknown	4	2		unknown	unknown	unknown	unknown		11.7	277.1	71	114	4
	72	4309741.8	641580.8	unknown	5	3		unknown	unknown	unknown	unknown		108.8	6.2	72	117	4
	73	4309732.6	641580.439	unknown	4	2		unknown	unknown	unknown	unknown		24.6	105.6	73	120	4
	74	4309750.9	641571.38	unknown	5	2		unknown	unknown	unknown	unknown		81.8	35.1	74	122	4
	75	4309753.5	641588.166	unknown	4	2		unknown	unknown	unknown	unknown		10.3	397.0	75	124	4
	76	4309745.9	641596.091	unknown	4	3		unknown	unknown	unknown	unknown		6.8	532.3	76	129	4
	77	4309738.6	641594.204	unknown	1	2		unknown	unknown	unknown	unknown		32.4	145.8	77	130	4
	78	4309731.3	641596.009	unknown	4	2		unknown	unknown	unknown	unknown		24.1	176.0	78	131	4
	79	4309723.2	641592.109	unknown	4	1		unknown	unknown	unknown	unknown		25.0	8498.1	79	134	4
	80	4309724.9	641583.677	unknown	5	2		unknown	unknown	unknown	unknown		47.7	47.6	80	136	4
	81	4309715.7	641601.877	unknown	5	2		unknown	unknown	unknown	unknown		169.2	113.4	81	31	5
	82	4309712.4	641610.357	unknown	4	2		unknown	unknown	unknown	unknown		20.1	102.7	82	32	5
	83	4309721.1	641611.781	unknown	4	2		unknown	unknown	unknown	unknown		24.7	162.5	83	33	5
	84	4309730	641610.967	unknown	4	2		unknown	unknown	unknown	unknown		20.2	101.0	84	34	5
	85	4309737.8	641607.016	unknown	5	2		unknown	unknown	unknown	unknown		113.7	44.5	85	37	5
	86	4309745.3	641608.311	unknown	4	2		unknown	unknown	unknown	unknown		21.6	87.6	86	38	5
	87	4309752.1	641611.402	unknown	4	2		unknown	unknown	unknown	unknown		10.2	58.6	87	39	5
	88	4309739.8	641623.504	unknown	5	3		unknown	unknown	unknown	unknown		130.2	22.2	88	51	5
	89	4309739.4	641631.781	unknown	4	5		unknown	unknown	unknown	unknown		24.3	0.5	89	72	5
	90	4309731.5	641627.126	unknown	4	2		unknown	unknown	unknown	unknown		21.9	152.2	90	74	5
	91	4309731.9	641636.34	unknown	4	2		unknown	unknown	unknown	unknown		15.3	1131.0	91	80	5
	92	4309721.2	641626.856	unknown	2	4		unknown	unknown	unknown	unknown		27.2	170.5	92	81	5
	93	4309713.1	641626.892	unknown	4	4		unknown	unknown	unknown	unknown		24.1	74.0	93	85	5
	94	4309710.1	641634.077	unknown	4	2		unknown	unknown	unknown	unknown		20.7	276.2	94	88	5
	95	4309696.3	641636.282	unknown	2	4		unknown	unknown	unknown	unknown		27.9	135.3	95	102	5
	96	4309701.6	641650.205	unknown	4	2		unknown	unknown	unknown	unknown		22.3	119.0	96	103	5
	97	4309713.1	641641.107	unknown	4	3		unknown	unknown	unknown	unknown		26.5	102.8	97	104	5
	98	4309720.2	641636.3	unknown	4	2		unknown	unknown	unknown	unknown		19.7	270.5	98	106	5

	99	4309720	641645.357	unknown	4	4		unknown	unknown	unknown	unknown		12.1	263.5	99	108	5
	100	4309724.7	641654.052	unknown	4	2		unknown	unknown	unknown	unknown		20.3	465.1	100	115	5
	101	4309733.5	641655.226	unknown	4	2		unknown	unknown	unknown	unknown		10.8	315.1	101	116	5
	102	4309740.7	641646.016	unknown	5	2		unknown	unknown	unknown	unknown		55.8	150.3	102	121	5
	103	4309749.2	641637.011	unknown	5	2		unknown	unknown	unknown	unknown		143.6	58.9	103	127	5
	104	4309746.1	641659.907	unknown	5	2		unknown	unknown	unknown	unknown		80.6	20.4	104	128	5
	105	4309736.6	641672.708	unknown	4	2		unknown	unknown	unknown	unknown		25.0	180.4	105	132	5
	106	4309744.7	641680.608	unknown	5	1		unknown	unknown	unknown	unknown		144.5	154.0	106	135	5
	107	4309743.4	641695.047	unknown	4	2		unknown	unknown	unknown	unknown		25.6	26.7	107	1	unknown
	108	4309737.9	641686.851	unknown	5	2		unknown	unknown	unknown	unknown		60.0	108.0	108	2	unknown
	109	4309737.3	641680.234	unknown	4	2		unknown	unknown	unknown	unknown		26.8	157.1	109	3	unknown
	110	4309721.7	641673.215	unknown	4	2		unknown	unknown	unknown	unknown		24.7	157.0	110	4	unknown
	111	4309721.9	641661.974	unknown	4	2		unknown	unknown	unknown	unknown		24.5	195.2	111	5	unknown
	112	4309717.5	641654.636	unknown	4	2		unknown	unknown	unknown	unknown		25.0	205.0	112	6	unknown
	113	4309713.9	641647.605	unknown	4	4		unknown	unknown	unknown	unknown		28.0	106.7	113	7	unknown
	114	4309699.4	641657.94	unknown	4	2		unknown	unknown	unknown	unknown		19.9	30.4	114	8	unknown
	115	4309694.9	641643.217	unknown	5	2		unknown	unknown	unknown	unknown		100.3	23.7	115	9	unknown
	116	4309688.5	641631.814	unknown	5	2		unknown	unknown	unknown	unknown		163.1	20.7	116	10	unknown
	117	4309682.4	641623.275	unknown	4	2		unknown	unknown	unknown	unknown		25.4	1069.5	117	11	unknown
	118	4309681.5	641638.28	unknown	2	4		unknown	unknown	unknown	unknown		12.8	80.3	118	12	unknown
	119	4309674.7	641644.173	unknown	2	2		unknown	unknown	unknown	unknown		12.8	116.4	119	13	unknown
	120	4309683.3	641646.856	unknown	4	2		unknown	unknown	unknown	unknown		10.2	375.1	120	14	unknown
	121	4309691.6	641660.955	unknown	5	1		unknown	unknown	unknown	unknown		63.5	108.8	121	15	unknown
	122	4309699	641666.668	unknown	4	1		unknown	unknown	unknown	unknown		19.6	160.2	122	16	unknown
	123	4309707.4	641670.519	unknown	1	2		unknown	unknown	unknown	unknown		13.0	428.9	123	17	unknown
	124	4309716.4	641670.839	unknown	4	2		unknown	unknown	unknown	unknown		23.2	51.1	124	18	unknown
	125	4309707.8	641677.969	unknown	2	2		unknown	unknown	unknown	unknown		14.0	329.9	125	19	unknown
	126	4309695.1	641686.269	unknown	2	2		unknown	unknown	unknown	unknown		14.0	329.9	126	20	unknown
	127	4309707.4	641689.422	unknown	5	2		unknown	unknown	unknown	unknown		95.8	67.8	127	21	unknown
	128	4309706.1	641696.886	unknown	5	2		unknown	unknown	unknown	unknown		125.7	91.1	128	22	unknown
	129	4309711.3	641704.339	unknown	4	2		unknown	unknown	unknown	unknown		9.2	405.9	129	23	unknown
	130	4309713.8	641693.268	unknown	4	1		unknown	unknown	unknown	unknown		20.6	113.4	130	24	unknown
	131	4309718.3	641687.108	unknown	4	1		unknown	unknown	unknown	unknown		22.3	176.4	131	25	unknown
	132	4309726.3	641690.088	unknown	5	1		unknown	unknown	unknown	unknown		145.9	216.2	132	26	unknown
	133	4309724.2	641697.044	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		133	27	unknown
	134	4309719	641703.259	unknown	4	1		unknown	unknown	unknown	unknown		17.2	409.9	134	28	unknown
	135	4309725.6	641705.748	unknown	5	2		unknown	unknown	unknown	unknown		50.3	29.0	135	29	unknown
	136	4309732.4	641703.428	unknown	4	2		unknown	unknown	unknown	unknown		26.2	93.1	136	30	unknown
	137	4309738.1	641699.6	unknown	2	2		unknown	unknown	unknown	unknown		14.4	105.0	137	133	unknown
	138	4309591.1	641465.635	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		138	138	unknown
	139	4309588.4	641456.706	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		139	139	unknown
	140	4309588.1	641447.882	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		140	140	unknown
	141	4309583.9	641441.677	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		141	141	unknown
	142	4309581.8	641450.056	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		142	142	unknown
	143	4309575.9	641458.805	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		143	143	unknown
	144	4309576.9	641442.021	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		144	144	unknown
	145	4309571.7	641434.735	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		145	145	unknown
	146	4309566.5	641426.008	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		146	146	unknown
	147	4309564.8	641443.934	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		147	147	unknown
	148	4309565.4	641459.268	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		148	148	unknown
	149	4309557.2	641460.646	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		149	149	unknown

	150	4309556.9	641450.195	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		150	150	unknown
	151	4309559.2	641438.969	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		151	151	unknown
	152	4309558	641426.679	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		152	152	unknown
	153	4309551.5	641418.817	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		153	153	unknown
	154	4309552.6	641432.497	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		154	154	unknown
	155	4309549	641445.842	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		155	155	unknown
	156	4309543.9	641436.55	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		156	156	unknown
	157	4309539.6	641422.284	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		157	157	unknown
	158	4309535.2	641432.679	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		158	158	unknown
	159	4309540.6	641449.221	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		159	159	unknown
	160	4309533.9	641457.338	unknown	unknown	unknown	unknown	unknown	unknown	unknown	unknown	not surveyed	unknown		160	160	unknown
	WES														WES	WES	
	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	inaccessible			1	WES1	N/A
	2			unknown	4	2			unknown	unknown		surveyed	19.5		2	WES6	1
	3			unknown	5	1			unknown	unknown		surveyed	58		3	WES8	1
	4			unknown	4	2			unknown	unknown		surveyed	25		4	WES5	3
	5			unknown	3	2			unknown	unknown		surveyed	16		5	WES9	3
	6			unknown	1	1			unknown	unknown		surveyed	31		6	WES2	4
	7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	inaccessible			7	WES4	4
	8			unknown	1	1			unknown	unknown		surveyed	35		8	WES10	4
	9			unknown	3	2			unknown	unknown		surveyed	11		9	WES3	5
	10			unknown	4	2			unknown	unknown		surveyed	25		10	WES7	N/A
	target	northing	easting	depth	type	confidence	weight	size	azimuth	declination	class	comments	Decay Const.		target	target	type
												library	46.8		48.3	48.3	
												library	45.0		49.5	49.5	
												library	42.3		13.5	13.5	
												library	41.2		16	16	
												library	33.6		33	33	
												library	33.0		155 mm	155 mm	
												library	31.9		11	11	
												library	31.3		105mm	105mm	
												library	23.1		9.45	9.45	
												library	20.7		6.3	6.3	
												library	19.9		47.5	47.5	
												library	15.6		16.5	16.5	
												library	14.6		15	15	
												library	14.4		72.5	72.5	
												library	13.5		81mm	81mm	
												library	12.2		24.25	24.25	
												library	11.5		48.5	48.5	
												library	8(?)		60mm	60mm	
												library	3(?)		20mm	20mm	

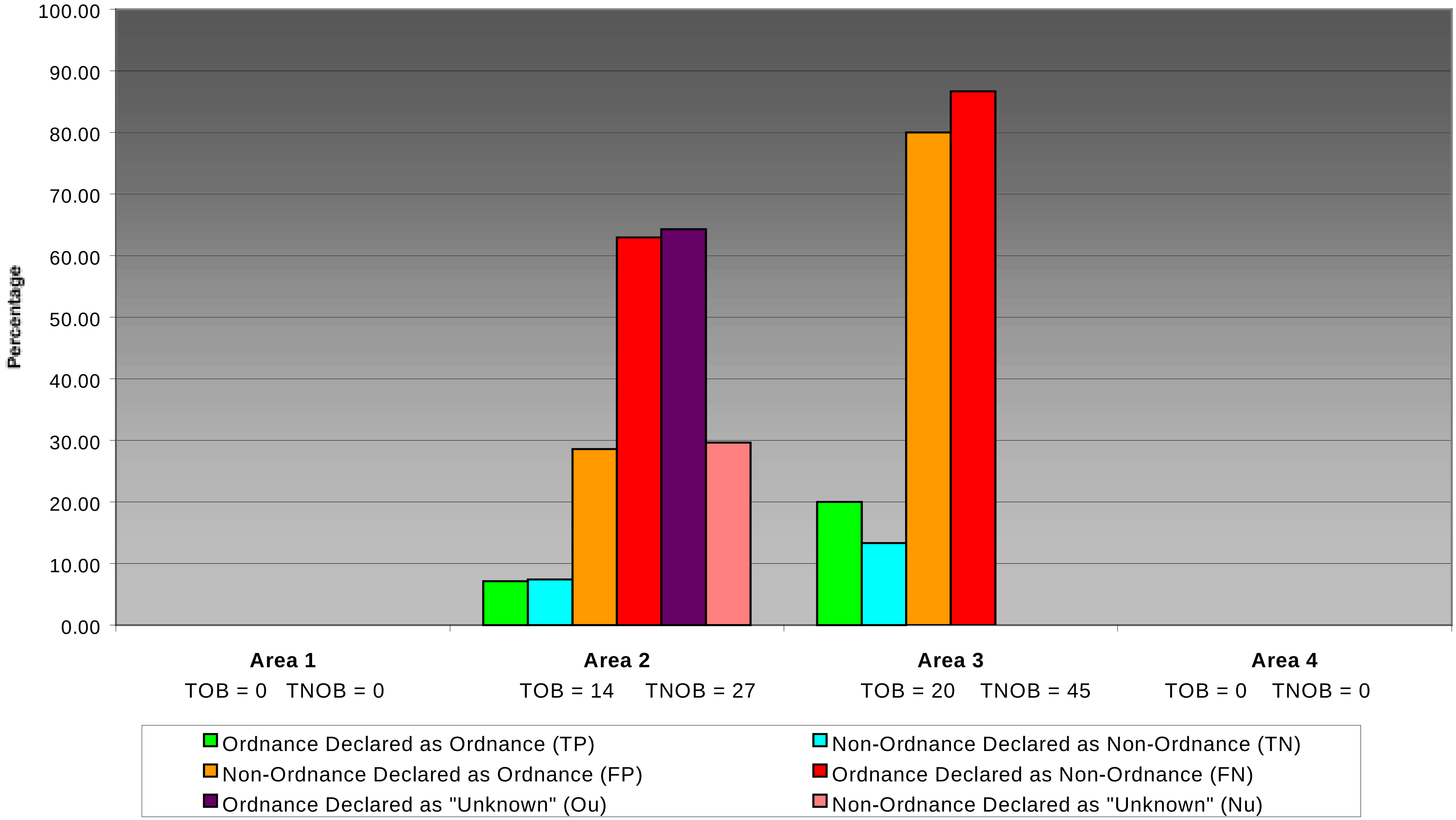
NOTES:

UXO or not UXO	Confidence
1= is UXO	1=highest
2 = probably is	2=moderate
3= unknown	3=unknown
4= probaly not	4= unsure
5=not UXO	5=lowest

RED font: Inversion parameters

BLUE font: Ranking targets by likelihood of being UXO.

JPG Phase IV, 40 Acre Site
APL - Percentage of TP, TN, FP, FN, & Unknowns for All Areas (1, 2, 3, 4)



%TP = (Correct Ordnance Declarations / TOB) x 100

%TN = (Correct Non-Ordnance Declarations / TNOB) x 100

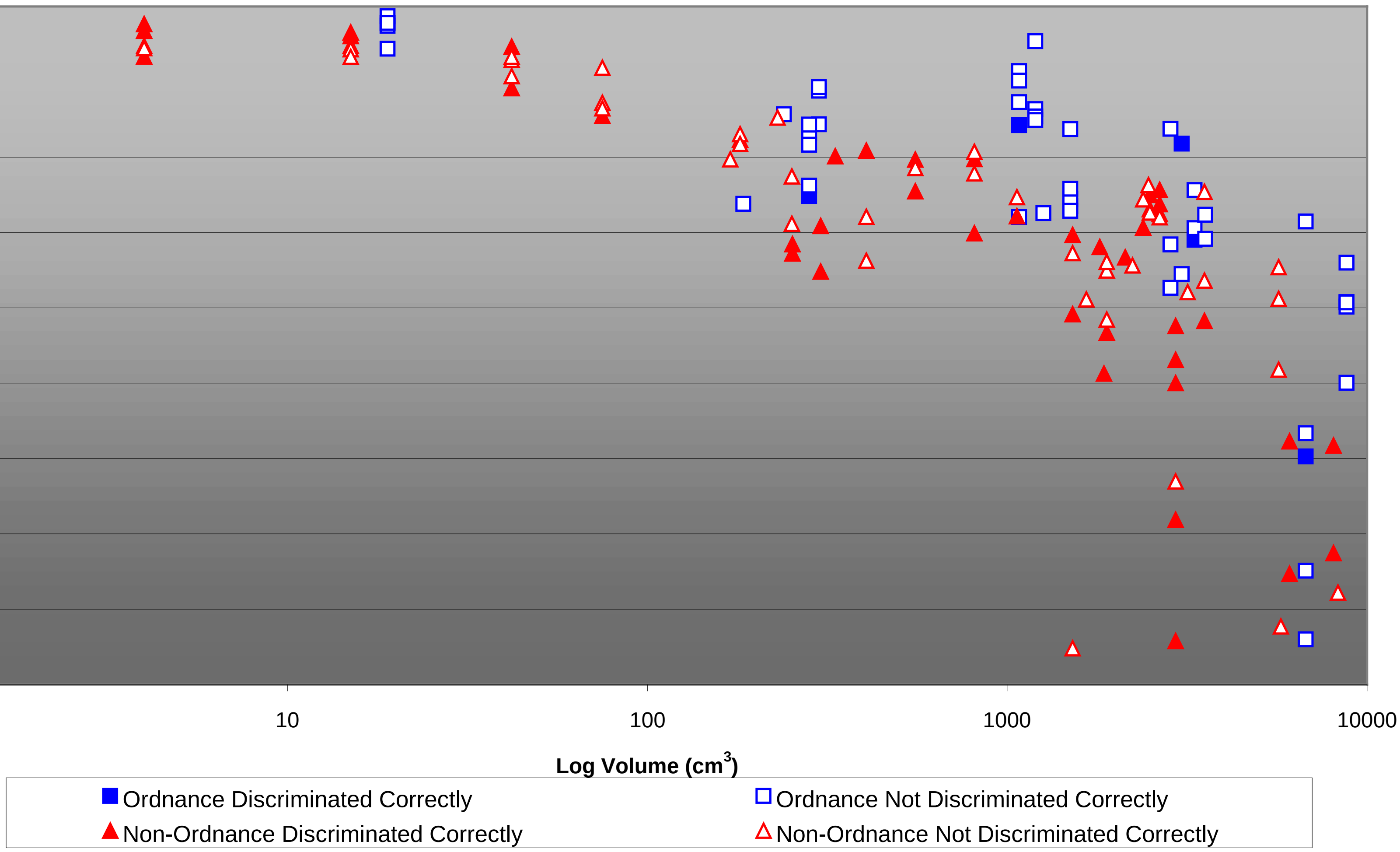
%FP = (Non-Ordnance Declared as Ordnance / TNOB) x 100

%Ou = (Ordnance Declared as Unknown / TOB) x 100

%Nu = (Non-Ordnance Declared as Unknown / TNOB) x 100

%FN = (Ordnance Declared as Non-Ordnance / TOB) x 100

JPG Phase IV, 40 Acre Site
APL - Depth Versus Target Volume



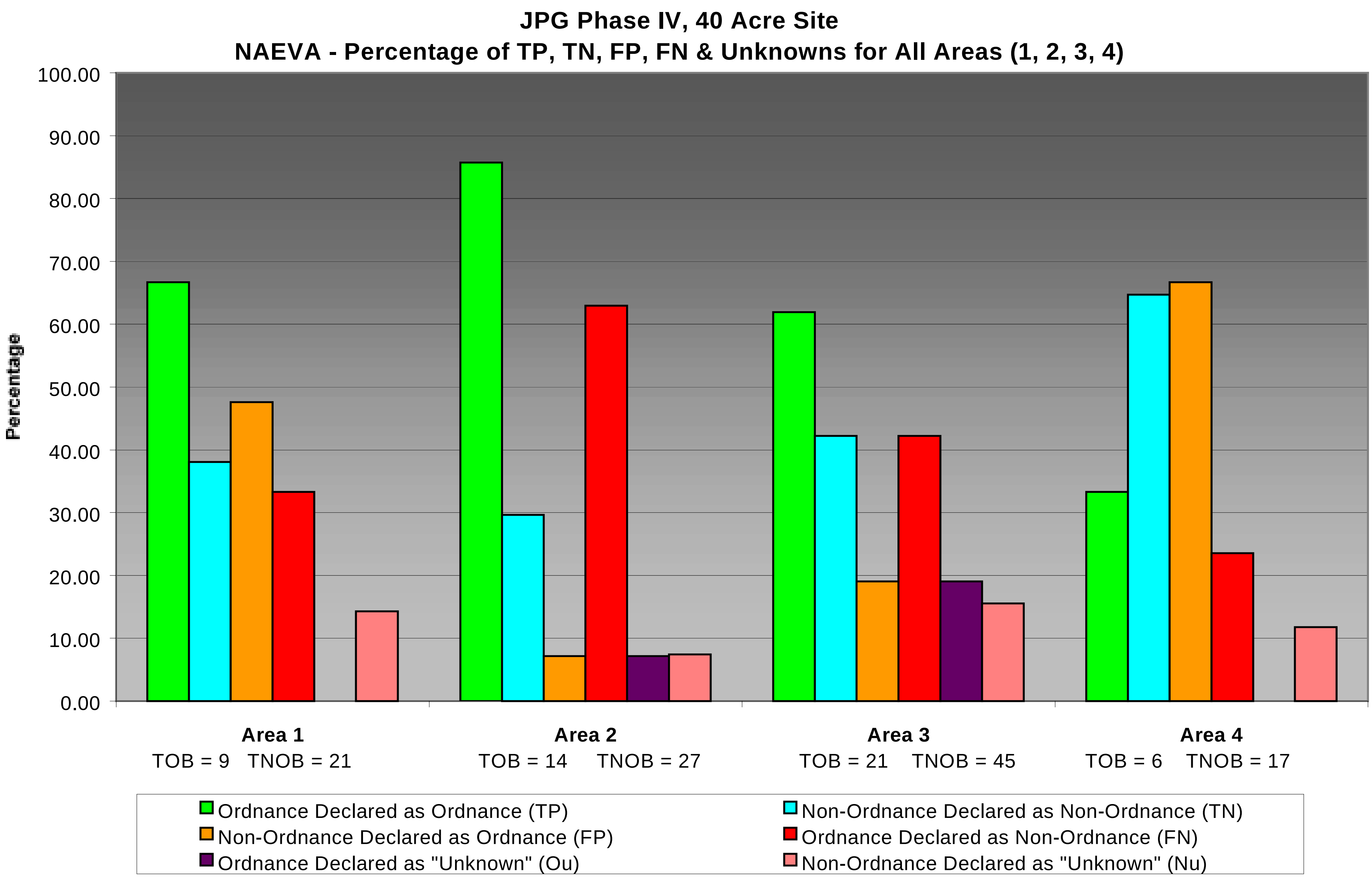
ssing from the Non-Ordnance Baseline

NAEVA

demonstrator	target	northing	easting	depth	type	confidence	weight	size	azimuth	declination	class	comments
003	52	4309493.911	641651.4811	0.53884	ordnance	high	moderate	medium	-99	-20	projectile	105 APERS
003	76	4309745.938	641596.0905	0.6304	ordnance	high	light	small	-99	-20	projectile	90 (105 HEAT, 152)
003	77	4309738.557	641594.2038	0.9144	ordnance	high	moderate	medium	-99	-20	projectile	152 (90, 105 HEAT)
003	78	4309731.319	641596.0086	1.2954	ordnance	high	light	small	-99	25	projectile	90 (155, 105 HEAT)
003	90	4309731.48	641627.1256	1.1202	ordnance	high	moderate	medium	-99	10	projectile	155 (152)
003	103	4309749.191	641637.0112	0.9528	ordnance	high	moderate	medium	-99	25	projectile	152, 155
003	104	4309746.146	641659.9074	1.143	ordnance	high	moderate	medium	-99	25	projectile	105 HEAT (152)
003	106	4309744.704	641680.6079	0.97	ordnance	high	moderate	medium	-99	22	projectile	105 HEAT
003	108	4309737.948	641686.851	1.0621	ordnance	high	moderate	medium	-99	0	projectile	155
003	125	4309707.773	641677.9689	0.525	ordnance	high	moderate	medium	-99	-10	projectile	105 HEAT (90)
003	148	4309565.402	641459.268	0.66922	ordnance	high	moderate	medium	-99	30	projectile	105 HEAT (152)
003	8	4309689.964	641519.4151	0.89042	ordnance	moderate	moderate	medium	-99	-10	projectile	155
003	14	4309700.031	641516.8877	0.82296	ordnance	moderate	moderate	medium	-99	-15	projectile	105 HEAT (90, 152)
003	22	4309648.858	641528.6493	0.74672	ordnance	moderate	moderate	medium	-99	-15	projectile	105 APERS (152)
003	23	4309640.757	641533.11	0.6935	ordnance	moderate	moderate	medium	-99	20	projectile	152 (105 HEAT)
003	27	4309637.331	641494.3316	0.66552	ordnance	moderate	moderate	medium	-99	-15	projectile	105 HEAT (152 or 90)
003	30	4309631.138	641481.1569	0.68648	ordnance	moderate	moderate	medium	-99	20	mortar	4.2" (81)
003	31	4309543.454	641641.2868	0.49658	ordnance	moderate	moderate	medium	-99	40	projectile	105 APERS
003	46	4309520.274	641636.6327	0.39312	ordnance	moderate	light	small	-99	10	mortar	81
003	47	4309518.956	641646.0144	0.4311	ordnance	moderate	moderate	medium	-99	0	mortar	81
003	53	4309502.131	641654.4569	1.40208	ordnance	moderate	moderate	medium	-99	40	projectile	152
003	56	4309478.608	641677.0733	UNKNOWN	ordnance	moderate	moderate	medium	-99	0	projectile	155 (152)
003	64	4309538.889	641668.4821	0.45432	ordnance	moderate	light	small	-99	0	mortar	81
003	65	4309547.094	641676.5865	0.5448	ordnance	moderate	light	medium	-99	10	projectile	105 HEAT (90)
003	67	4309537.076	641680.9031	0.35336	ordnance	moderate	light	small	-99	30	projectile	57
003	68	4309530.699	641686.6266	0.48768	ordnance	moderate	light	small	-99	0	mortar	81
003	79	4309723.153	641592.1086	0.4992	ordnance	moderate	moderate	medium	-99	45	projectile	105 APERS
003	92	4309721.188	641626.856	1.524	ordnance	moderate	moderate	medium	-99	10	projectile	152
003	94	4309710.066	641634.0774	1.7526	ordnance	moderate	moderate	medium	-99	45	projectile	152 (105 HEAT)
003	98	4309720.176	641636.2995	0.8053	ordnance	moderate	light	small	-99	10	projectile	90
003	117	4309682.41	641623.2747	0.761	ordnance	moderate	moderate	medium	-99	0	projectile	155 (152)
003	120	4309683.273	641646.8557	0.854	ordnance	moderate	moderate	medium	-99	-20	projectile	152 (155)
003	129	4309711.326	641704.3392	0.5154	ordnance	moderate	light	small	-99	0	mortar	81
003	130	4309713.816	641693.2683	0.63576	ordnance	moderate	moderate	medium	-99	0	projectile	105 HEAT or 90
003	134	4309719.025	641703.2589	0.735	ordnance	moderate	moderate	medium	-99	-10	projectile	105 HEAT
003	137	4309738.07	641699.6002	1.0668	ordnance	moderate	moderate	medium	-99	0	projectile	152
003	140	4309588.103	641447.8817	1.6002	ordnance	moderate	moderate	medium	-99	-20	mortar	4.2"
003	143	4309575.883	641458.8054	0.85344	ordnance	moderate	moderate	medium	-99	-10	projectile	152
003	151	4309559.189	641438.9692	0.7641	ordnance	moderate	light	small	-99	-10	projectile	90
003	154	4309552.565	641432.4971	0.5829	ordnance	moderate	light	small	-99	0	projectile	90
003	160	4309533.937	641457.3376	0.79672	ordnance	moderate	moderate	medium	-99	-17	projectile	105 HEAT (152, 90)
003	2	4309714.72	641491.1256	0.63004	ordnance	low	light	small	-99	30	mortar	4.2"
003	3	4309723.489	641489.9575	0.36312	ordnance	low	light	small	-99	45	projectile	57
003	5	4309699.315	641487.2952	0.1	ordnance	low	light	small	-99	40	projectile	20
003	7	4309695.306	641497.248	0.39624	ordnance	low	light	small	-99	30	projectile	20
003	11	4309711.925	641524.5496	0.9144	ordnance	low	moderate	medium	-99	0	projectile	105 HEAT(90)
003	16	4309685.348	641538.4751	1.70688	ordnance	low	moderate	medium	-99	-40	projectile	152 (155)
003	18	4309662.058	641508.739	0.4386	ordnance	low	light	small	-99	45	mortar	81 (57)
003	24	4309633.699	641524.6555	1.6764	ordnance	low	moderate	medium	-99	10	projectile	155 or 152 or 105 HEAT
003	25	4309647.941	641494.9067	1.03632	ordnance	low	moderate	medium	-99	-10	projectile	152 (90 or 105 HEAT)
003	26	4309636.739	641511.6791	0.39624	ordnance	low	light	small	-99	0	projectile	57
003	33	4309536.121	641637.0525	0.12894	ordnance	low	light	small	-99	45	mortar	60
003	35	4309533.289	641646.4195	0.8135	ordnance	low	moderate	medium	-99	22	projectile	152
003	36	4309531.066	641627.8857	0.741	ordnance	low	moderate	medium	-99	-15	projectile	105 HEAT (152)
003	39	4309517.603	641625.2732	0.24384	ordnance	low	light	small	-99	10	mortar	81
003	40	4309531.608	641607.3828	0.46432	ordnance	low	light	small	-99	0	projectile	57
003	45	4309513.314	641635.2695	0.58028	ordnance	low	light	small	-99	45	mortar	81
003	59	4309492.008	641680.9647	0.8172	ordnance	low	moderate	medium	-99	10	projectile	152
003	61	4309511.168	641664.395	0.24384	ordnance	low	light	small	-99	0	mortar	60
003	62	4309517.978	641669.516	0.27432	ordnance	low	light	small	-99	0	projectile	57

003	63	4309526.938	641666.1392	0.25216	ordnance	low	light	small	-99	20	projectile	57
003	80	4309724.92	641583.6774	UNKNOWN	ordnance	low	light	small	-99	0	mortar	81 (57)
003	81	4309715.746	641601.877	0.6096	ordnance	low	light	small	-99	0	mortar	60
003	91	4309731.88	641636.3398	0.6729	ordnance	low	moderate	medium	-99	5	projectile	152 or 105 HEAT
003	96	4309701.645	641650.2054	1.7526	ordnance	low	moderate	medium	-99	-40	projectile	105 HEAT (90)
003	99	4309719.96	641645.3574	0.4517	ordnance	low	moderate	medium	-99	-20	projectile	105 HEAT (90)
003	100	4309724.723	641654.0519	0.5523	ordnance	low	moderate	medium	-99	0	projectile	155 (105 HEAT, 90)
003	101	4309733.474	641655.2261	0.6098	ordnance	low	moderate	medium	-99	-20	projectile	152 (105 HEAT, 90)
003	110	4309721.726	641673.2145	0.9906	ordnance	low	moderate	medium	-99	-10	projectile	152 (105 HEAT)
003	114	4309699.443	641657.9399	0.38	ordnance	low	light	small	-99	10	projectile	90
003	122	4309699.042	641666.668	0.615	ordnance	low	moderate	medium	-99	-10	projectile	152 (or 105 HEAT)
003	123	4309707.427	641670.5189	0.4467	ordnance	low	light	small	-99	10	mortar	81 (57)
003	133	4309724.23	641697.0443	0.76292	ordnance	low	moderate	medium	-99	0	projectile	152
003	135	4309725.577	641705.748	1.524	ordnance	low	moderate	medium	-99	10	projectile	155 (105 HEAT)
003	139	4309588.369	641456.7064	0.9609	ordnance	low	moderate	medium	-99	-15	projectile	105 HEAT (152)
003	142	4309581.781	641450.0555	0.6435	ordnance	low	light	small	-99	10	projectile	90
003	145	4309571.699	641434.7353	0.4342	ordnance	low	light	small	-99	60	projectile	57 (or -60 declination)
003	147	4309564.8	641443.9335	0.5848	ordnance	low	moderate	medium	-99	20	mortar	4.2" (81, 90)
003	149	4309557.232	641460.6456	0.64754	ordnance	low	moderate	medium	-99	20	mortar	4.2"
003	150	4309556.935	641450.1952	0.72648	ordnance	low	moderate	medium	-99	-10	mortar	152
003	152	4309557.98	641426.6787	0.646	ordnance	low	light	small	-99	20	mortar	81 (or -20 declination)
003	10	4309671.286	641533.8465	1.8288	unknown	unknown	unknown	unknown	-99	-99	unknown	too deep
003	13	4309684.844	641503.1903	UNKNOWN	unknown	unknown	unknown	unknown	-99	-99	unknown	too deep
003	29	4309639.57	641477.0149	1.3112	unknown	unknown	moderate	medium	-99	-99	unknown	
003	34	4309542.756	641627.6585	UNKNOWN	unknown	unknown	unknown	unknown	-99	-99	unknown	
003	38	4309524.923	641621.8741	0.21336	unknown	unknown	light	small	-99	-99	unknown	if ordnance, 20
003	51	4309491.989	641640.4295	1.8288	unknown	unknown	moderate	medium	-99	-99	unknown	too deep
003	72	4309741.848	641580.8004	0.1	unknown	unknown	light	small	-99	-99	unknown	
003	73	4309732.612	641580.4389	UNKNOWN	unknown	unknown	unknown	unknown	-99	-99	unknown	too deep
003	97	4309713.054	641641.107	UNKNOWN	unknown	unknown	unknown	unknown	-99	-99	unknown	too deep
003	105	4309736.616	641672.7084	UNKNOWN	unknown	unknown	unknown	unknown	-99	-99	unknown	too deep
003	109	4309737.304	641680.2341	UNKNOWN	unknown	unknown	unknown	unknown	-99	-99	unknown	too deep
003	112	4309717.48	641654.636	1.8288	unknown	unknown	unknown	unknown	-99	-99	unknown	too deep
003	113	4309713.893	641647.605	UNKNOWN	unknown	unknown	unknown	unknown	-99	-99	unknown	too deep
003	115	4309694.869	641643.2166	UNKNOWN	unknown	unknown	unknown	unknown	-99	-99	unknown	
003	116	4309688.47	641631.8135	UNKNOWN	unknown	unknown	unknown	unknown	-99	-99	unknown	too deep
003	118	4309681.458	641638.2797	0.5	unknown	unknown	unknown	unknown	-99	-99	unknown	too deep
003	136	4309732.423	641703.4278	UNKNOWN	unknown	unknown	unknown	unknown	-99	-99	unknown	too deep
003	156	4309543.94	641436.5504	UNKNOWN	unknown	unknown	unknown	unknown	-99	-99	unknown	too deep
003	158	4309535.239	641432.6788	UNKNOWN	unknown	unknown	light	small	-99	-99	unknown	too deep
003	6	4309707.478	641478.9258	0.24384	nonordnance	low	unknown	unknown	-99	-99	unknown	
003	17	4309666.496	641517.3798	0.19764	nonordnance	low	light	small	-99	-99	unknown	
003	28	4309648.346	641480.0782	1.15824	nonordnance	low	light	small	-99	-99	unknown	if ordnance, 81
003	32	4309539.567	641651.1384	0.9134	nonordnance	low	moderate	medium	-99	-99	unknown	
003	37	4309527.775	641639.3732	UNKNOWN	nonordnance	low	unknown	unknown	-99	-99	unknown	
003	54	4309488.642	641658.9909	UNKNOWN	nonordnance	low	unknown	unknown	-99	-99	unknown	
003	55	4309481.433	641663.2956	0.70104	nonordnance	low	unknown	unknown	-99	-99	unknown	If ordnance, 152
003	58	4309485.956	641684.1457	1.00584	nonordnance	low	unknown	unknown	-99	-99	unknown	if ordnance, 4.2"mortar
003	74	4309750.911	641571.3801	0.67056	nonordnance	low	light	small	-99	-99	unknown	
003	75	4309753.53	641588.1663	UNKNOWN	nonordnance	low	unknown	unknown	-99	-99	unknown	
003	86	4309745.253	641608.3113	0.5334	nonordnance	low	unknown	unknown	-99	-99	unknown	if ordnance, 57
003	87	4309752.12	641611.4021	0.5334	nonordnance	low	unknown	unknown	-99	-99	unknown	if ordnance, 57
003	93	4309713.134	641626.8921	1.524	nonordnance	low	moderate	medium	-99	-99	unknown	
003	95	4309696.285	641636.2818	1.2954	nonordnance	low	moderate	medium	-99	-99	unknown	if ordnance, 152
003	107	4309743.431	641695.0465	UNKNOWN	nonordnance	low	unknown	unknown	-99	-99	unknown	
003	111	4309721.851	641661.9743	0.6858	nonordnance	low	light	small	-99	-99	unknown	
003	126	4309695.101	641686.2686	0.67052	nonordnance	low	moderate	medium	-99	-99	unknown	
003	132	4309726.261	641690.0878	1.0958	nonordnance	low	moderate	medium	-99	-99	unknown	
003	138	4309591.082	641465.635	0.656	nonordnance	low	light	small	-99	-99	unknown	if ordnance, 105 HEAT
003	144	4309576.944	641442.021	0.381	nonordnance	low	light	small	-99	-99	unknown	
003	146	4309566.485	641426.0077	0.52	nonordnance	low	light	small	-99	-99	unknown	
003	155	4309548.951	641445.8415	0.1	nonordnance	low	light	small	-99	-99	unknown	
003	157	4309539.57	641422.2841	0.3048	nonordnance	low	light	small	-99	-99	unknown	
003	1	4309722.703	641501.6964	0.57504	nonordnance	moderate	unknown	unknown	-99	-99	unknown	

003	4	4309712.451	641508.1419	0.45884	nonordnance	moderate	light	small	-99	-99	unknown	
003	9	4309676.382	641524.9589	0.80446	nonordnance	moderate	moderate	unknown	-99	-99	unknown	
003	15	4309698.16	641541.1325	0.8672	nonordnance	moderate	moderate	medium	-99	-99	unknown	if ordnance, 81
003	19	4309660.158	641525.2945	0.64008	nonordnance	moderate	light	small	-99	-99	unknown	if ordnance, 57
003	20	4309656.014	641500.356	0.54864	nonordnance	moderate	light	small	-99	-99	unknown	if ordnance, 57 or 60
003	21	4309647.792	641513.1396	0.54278	nonordnance	moderate	light	small	-99	-99	unknown	if ordnance, 57 or 60
003	41	4309525.663	641610.2988	0.70104	nonordnance	moderate	light	small	-99	-99	unknown	
003	42	4309518.166	641604.8853	0.30038	nonordnance	moderate	light	small	-99	-99	unknown	
003	43	4309512.933	641612.7706	0.51816	nonordnance	moderate	light	small	-99	-99	unknown	
003	57	4309487.487	641674.0428	0.7285	nonordnance	moderate	moderate	medium	-99	-99	unknown	
003	60	4309497.795	641670.6678	0.55254	nonordnance	moderate	light	small	-99	-99	unknown	
003	71	4309511.257	641685.8505	UNKNOWN	nonordnance	moderate	light	small	-99	-99	unknown	
003	83	4309721.053	641611.7808	0.3048	nonordnance	moderate	light	small	-99	-99	unknown	
003	84	4309730.047	641610.9674	0.4572	nonordnance	moderate	unknown	unknown	-99	-99	unknown	
003	85	4309737.758	641607.0157	0.3105	nonordnance	moderate	light	small	-99	-99	unknown	
003	88	4309739.79	641623.5044	0.3455	nonordnance	moderate	light	small	-99	-99	unknown	
003	89	4309739.383	641631.7813	0.3961	nonordnance	moderate	light	small	-99	-99	unknown	
003	102	4309740.661	641646.0157	0.4223	nonordnance	moderate	light	small	-99	-99	unknown	
003	124	4309716.362	641670.8394	0.44	nonordnance	moderate	unknown	unknown	-99	-99	unknown	
003	141	4309583.901	641441.6773	0.5429	nonordnance	moderate	light	small	-99	-99	unknown	
003	159	4309540.58	641449.2209	0.36576	nonordnance	moderate	light	small	-99	-99	unknown	
003	12	4309704.597	641533.3263	0.47634	nonordnance	high	light	small	-99	-99	unknown	
003	44	4309506.92	641625.3579	0.54504	nonordnance	high	light	small	-99	-99	unknown	
003	48	4309511.734	641648.6154	0.6048	nonordnance	high	moderate	medium	-99	-99	unknown	
003	49	4309505.22	641641.0964	0.60254	nonordnance	high	unknown	unknown	-99	-99	unknown	
003	50	4309500.508	641633.4921	0.64008	nonordnance	high	light	small	-99	-99	unknown	
003	66	4309543.169	641685.2422	UNKNOWN	nonordnance	high	unknown	unknown	-99	-99	unknown	
003	69	4309529.651	641675.5922	UNKNOWN	nonordnance	high	light	medium	-99	-99	unknown	
003	70	4309521.627	641686.1291	0.62778	nonordnance	high	unknown	unknown	-99	-99	unknown	
003	82	4309712.379	641610.3568	0.3048	nonordnance	high	unknown	unknown	-99	-99	unknown	
003	119	4309674.722	641644.1734	0.381	nonordnance	high	light	small	-99	-99	unknown	
003	121	4309691.65	641660.9546	UNKNOWN	nonordnance	high	unknown	unknown	-99	-99	unknown	
003	127	4309707.395	641689.4222	1.31064	nonordnance	high	unknown	unknown	-99	-99	unknown	
003	128	4309706.081	641696.8856	1.00584	nonordnance	high	unknown	unknown	-99	-99	unknown	
003	131	4309718.268	641687.1084	0.6223	nonordnance	high	moderate	medium	-99	-99	unknown	
003	153	4309551.55	641418.8173	0.5698	nonordnance	high	moderate	medium	-99	-99	unknown	



%TP = (Correct Ordnance Declarations / TOB) x 100

%TN = (Correct Non-Ordnance Declarations / TNOB) x 100

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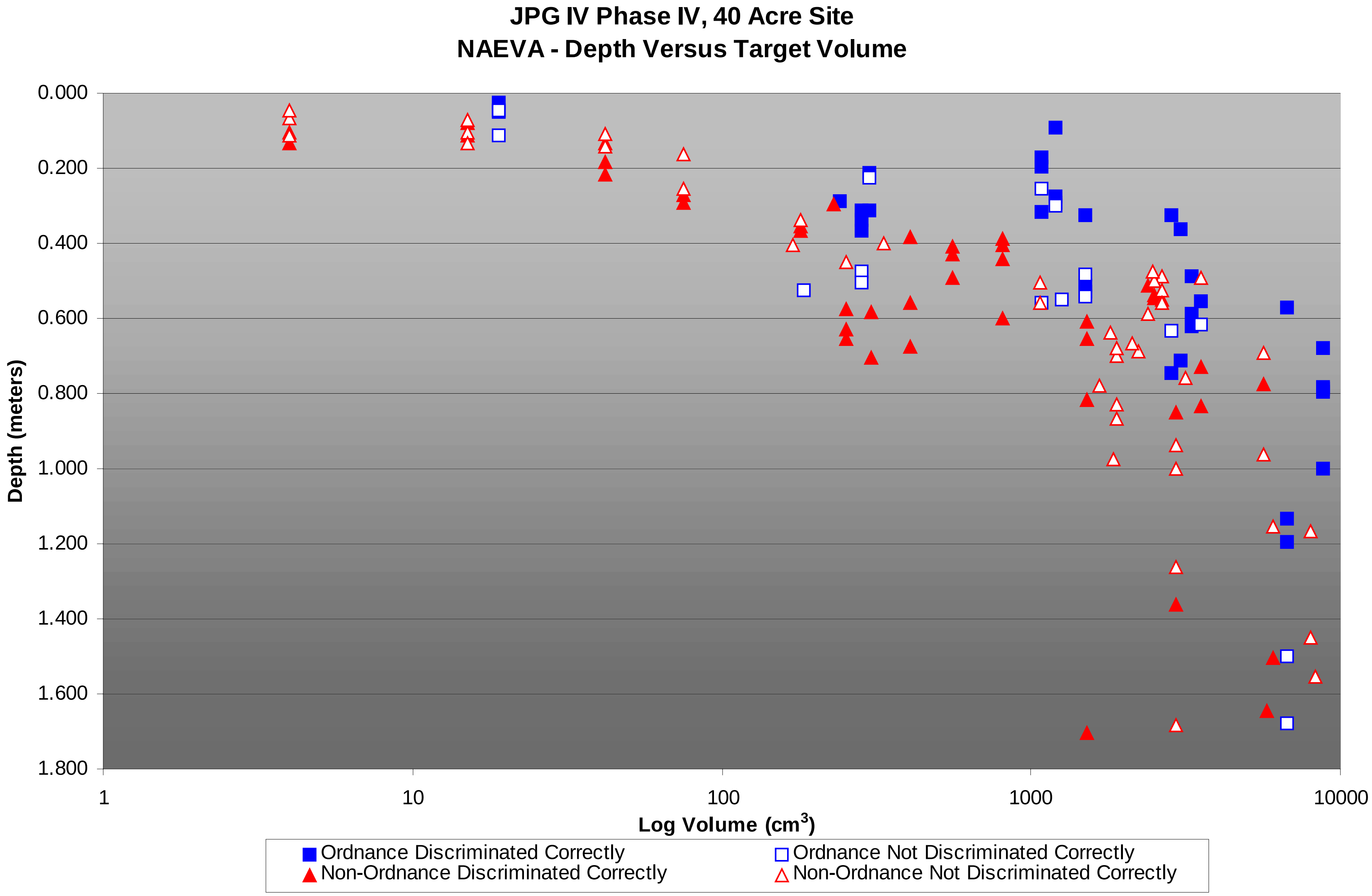


25 Targets missing from the Non-Ordnance Baseline

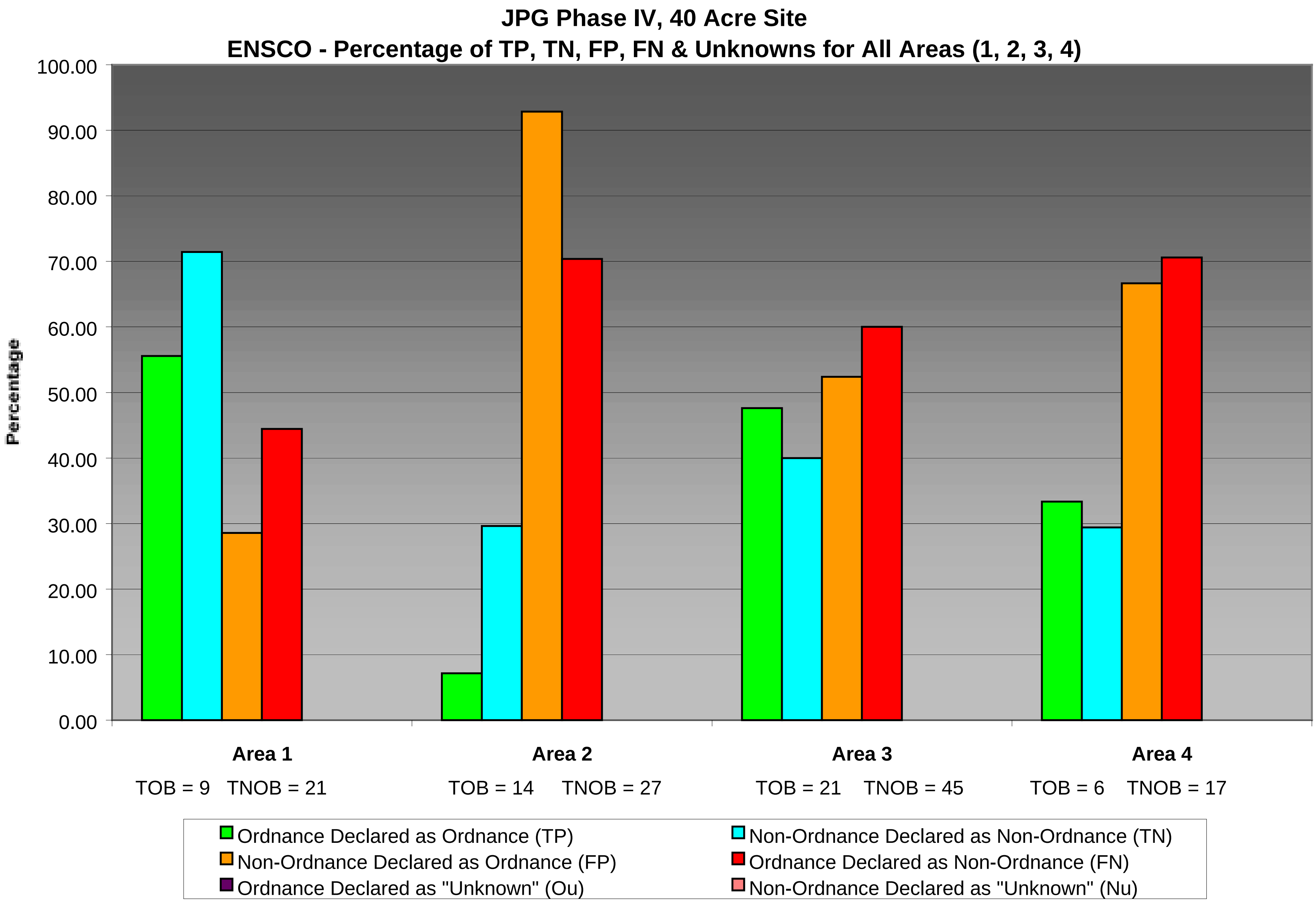
ENSCO

demon	target	northing	easting	depth	type	confidence	weight	size	azimuth	declination	class	comments
7	16	4309685.3480	641538.4751	0.8636	ordnance	high	moderate	medium	-99	-99	projectile	105-mm projectile
7	17	4309666.4957	641517.3798	0.210312	ordnance	high	light	small	45	45	mortar	60-mm mortar
7	119	4309674.7221	641644.1734	0.496824	ordnance	high	light	small	0	45	mortar	81-mm mortar (illumination)
7	134	4309719.0252	641703.2589	0.955132364	ordnance	high	light	small	180	45	mortar	81-mm mortar (illumination)
7	5	4309699.3145	641487.2952	0.300445714	ordnance	moderate	light	small	315	0	projectile	20-mm projectile
7	10	4309671.2855	641533.8465	1.2954	ordnance	moderate	moderate	medium	200	20	projectile	155-mm projectile
7	15	4309698.1601	641541.1325	0.712869143	ordnance	moderate	moderate	medium	90	45	mortar	4.2-in mortar
7	19	4309660.1581	641525.2945	0.501468571	ordnance	moderate	light	small	0	0	mortar	81-mm mortar
7	25	4309647.9414	641494.9067	0.751114286	ordnance	moderate	moderate	medium	45	45	projectile	155-mm projectile
7	29	4309639.5701	641477.0149	0.9398	ordnance	moderate	moderate	medium	0	25	projectile	155-mm projectile
7	39	4309517.6033	641625.2732	0.261112	ordnance	moderate	light	small	0	90	mortar	60-mm mortar
7	41	4309525.6634	641610.2988	0.624378182	ordnance	moderate	light	small	90	45	projectile	90-mm projectile
7	50	4309500.5075	641633.4921	0.6096	ordnance	moderate	light	small	45	0	projectile	76-mm projectile
7	60	4309497.7949	641670.6678	0.535339636	ordnance	moderate	light	small	90	0	projectile	76-mm projectile
7	66	4309543.1691	641685.2422	0.344146909	ordnance	moderate	light	small	90	0	mortar	81-mm mortar
7	70	4309521.6268	641686.1291	0.401227636	ordnance	moderate	light	small	25	20	mortar	81-mm mortar
7	72	4309741.8481	641580.8004	0.045066857	ordnance	moderate	light	small	0	0	projectile	20-mm projectile
7	78	4309731.3193	641596.0086	0.315468	ordnance	moderate	light	small	45	0	mortar	57-mm mortar
7	84	4309730.0474	641610.9674	0.486446286	ordnance	moderate	light	small	315	25	projectile	90-mm projectile
7	95	4309696.2846	641636.2818	0.617002286	ordnance	moderate	moderate	medium	0	0	mortar	4.2-in mortar
7	106	4309744.7036	641680.6079	0.936844364	ordnance	moderate	moderate	medium	45	30	projectile	105-mm projectile
7	109	4309737.3039	641680.2341	0.497101091	ordnance	moderate	light	small	45	0	mortar	57-mm mortar
7	124	4309716.3620	641670.8394	0.482890286	ordnance	moderate	light	small	90	0	mortar	60-mm mortar
7	132	4309726.2612	641690.0878	0.570846857	ordnance	moderate	moderate	medium	20	45	mortar	4.2-in mortar
7	136	4309732.4228	641703.4278	0.903514286	ordnance	moderate	moderate	medium	160	0	projectile	105-mm projectile
7	137	4309738.0695	641699.6002	0.647046857	ordnance	moderate	moderate	medium	45	-99	mortar	4.2-in mortar
7	138	4309591.0823	641465.6350	0.552268571	ordnance	moderate	light	small	45	45	mortar	76-mm mortar
7	142	4309581.7806	641450.0555	0.556913143	ordnance	moderate	light	small	45	0	mortar	81-mm mortar
7	146	4309566.4851	641426.0077	0.497101091	ordnance	moderate	light	small	-99	-99	mortar	57-mm mortar
7	160	4309533.9374	641457.3376	0.747558286	ordnance	moderate	moderate	medium	225	45	projectile	155-mm projectile
7	11	4309711.9248	641524.5496	0.666713714	ordnance	low	light	small	45	0	projectile	76-mm projectile
7	20	4309656.0144	641500.3560	0.391668	ordnance	low	light	small	0	0	mortar	60-mm mortar
7	21	4309647.7922	641513.1396	0.442468	ordnance	low	light	small	0	45	mortar	60-mm mortar
7	53	4309502.1307	641654.4569	0.439743273	ordnance	low	moderate	medium	-99	-99	projectile	155-mm projectile
7	55	4309481.4325	641663.2956	0.515943273	ordnance	low	light	small	315	45	mortar	81-mm mortar
7	69	4309529.6511	641675.5922	0.458585455	ordnance	low	light	small	0	45	mortar	60-mm mortar
7	81	4309715.7457	641601.8770	0.270401143	ordnance	low	light	small	45	0	mortar	60-mm mortar
7	83	4309721.0529	641611.7808	0.270401143	ordnance	low	light	small	0	90	mortar	60-mm mortar
7	90	4309731.4799	641627.1256	0.721069714	ordnance	low	light	small	180	45	projectile	90-mm projectile
7	92	4309721.1882	641626.8560	0.267115636	ordnance	low	moderate	medium	-99	-99	projectile	105-mm projectile
7	94	4309710.0658	641634.0774	0.9144	ordnance	low	light	medium	-99	-99	projectile	152-mm projectile
7	98	4309720.1761	641636.2995	0.603068571	ordnance	low	moderate	medium	45	0	projectile	105-mm projectile
7	100	4309724.7227	641654.0519	0.687469143	ordnance	low	moderate	medium	0	0	mortar	4.2-in mortar
7	104	4309746.1455	641659.9074	0.547624	ordnance	low	light	small	30	0	projectile	76-mm projectile
7	107	4309743.4314	641695.0465	1.0668	ordnance	low	light	medium	-99	-99	projectile	152-mm projectile
7	111	4309721.8511	641661.9743	0.768313714	ordnance	low	light	small	315	30	projectile	90-mm projectile
7	114	4309699.4430	641657.9399	0.85344	ordnance	low	light	medium	-99	-99	projectile	152-mm projectile
7	122	4309699.0424	641666.6680	0.541890857	ordnance	low	light	small	0	0	projectile	90-mm projectile
7	127	4309707.3951	641689.4222	0.577668571	ordnance	low	light	small	0	0	projectile	76-mm projectile
7	128	4309706.0809	641696.8856	0.603068571	ordnance	low	light	small	270	45	projectile	90-mm projectile, 2nd target 1.2m north of pin flag
7	131	4309718.2679	641687.1084	0.483985455	ordnance	low	light	small	315	0	mortar	81-mm mortar
7	135	4309725.5767	641705.7480	0.762	ordnance	low	moderate	medium	-99	-99	projectile	105-mm projectile
7	140	4309588.1029	641447.8817	0.6858	ordnance	low	moderate	medium	45	-99	projectile	155-mm projectile
7	144	4309576.9436	641442.0210	0.336223429	ordnance	low	light	small	225	45	mortar	60-mm mortar
7	145	4309571.6988	641434.7353	0.381	ordnance	low	light	small	45	-99	projectile	76-mm projectile
7	57	4309487.4870	641674.0428	0.592420364	nonordnance	low	unknown	unknown	-99	-99		
7	75	4309753.5295	641588.1663	0.150222857	nonordnance	low	unknown	unknown	-99	-99		
7	76	4309745.9382	641596.0905	0.532601714	nonordnance	low	unknown	unknown	-99	-99		
7	77	4309738.5574	641594.2038	0.566202286	nonordnance	low	unknown	unknown	-99	-99		
7	93	4309713.1336	641626.8921	0.5	nonordnance	low	unknown	unknown	-99	-99		empty hole

7	151	4309559.1890	641438.9692	0.28956	nonordnance	low	unknown	unknown	-99	-99		
7	3	4309723.4889	641489.9575	0.225334286	nonordnance	moderate	unknown	unknown	-99	-99		
7	6	4309707.4780	641478.9258	0.127	nonordnance	moderate	unknown	unknown	-99	-99		
7	7	4309695.3058	641497.2480	0.120178286	nonordnance	moderate	unknown	unknown	-99	-99		
7	13	4309684.8441	641503.1903	0.5	nonordnance	moderate	unknown	unknown	-99	-99		empty hole
7	18	4309662.0578	641508.7390	0.225334286	nonordnance	moderate	unknown	unknown	-99	-99		
7	22	4309648.8579	641528.6493	0.647046857	nonordnance	moderate	unknown	unknown	-99	-99		
7	24	4309633.6994	641524.6555	0.5	nonordnance	moderate	unknown	unknown	-99	-99		empty hole
7	26	4309636.7391	641511.6791	0.246089714	nonordnance	moderate	unknown	unknown	-99	-99		
7	27	4309637.3312	641494.3316	0.481801714	nonordnance	moderate	unknown	unknown	-99	-99		
7	28	4309648.3457	641480.0782	0.5	nonordnance	moderate	unknown	unknown	-99	-99		empty hole
7	32	4309539.5670	641651.1384	0.821851636	nonordnance	moderate	unknown	unknown	-99	-99		
7	33	4309536.1208	641637.0525	0.299350545	nonordnance	moderate	unknown	unknown	-99	-99		
7	34	4309542.7559	641627.6585	0.228877091	nonordnance	moderate	unknown	unknown	-99	-99		
7	37	4309527.7748	641639.3732	0.229154182	nonordnance	moderate	unknown	unknown	-99	-99		
7	43	4309512.9333	641612.7706	0.312189091	nonordnance	moderate	unknown	unknown	-99	-99		
7	44	4309506.9198	641625.3579	0.344146909	nonordnance	moderate	unknown	unknown	-99	-99		
7	47	4309518.9561	641646.0144	0.344146909	nonordnance	moderate	unknown	unknown	-99	-99		
7	51	4309491.9892	641640.4295	0.5	nonordnance	moderate	unknown	unknown	-99	-99		empty hole
7	58	4309485.9556	641684.1457	0.834690182	nonordnance	moderate	unknown	unknown	-99	-99		
7	61	4309511.1684	641664.3950	0.172073455	nonordnance	moderate	unknown	unknown	-99	-99		
7	68	4309530.6987	641686.6266	0.343869818	nonordnance	moderate	unknown	unknown	-99	-99		
7	71	4309511.2566	641685.8505	0.248550545	nonordnance	moderate	unknown	unknown	-99	-99		
7	79	4309723.1531	641592.1086	0.401504727	nonordnance	moderate	unknown	unknown	-99	-99		
7	80	4309724.9196	641583.6774	0.165245143	nonordnance	moderate	unknown	unknown	-99	-99		
7	82	4309712.3792	641610.3568	0.421712571	nonordnance	moderate	unknown	unknown	-99	-99		
7	86	4309745.2530	641608.3113	0.270401143	nonordnance	moderate	unknown	unknown	-99	-99		
7	87	4309752.1200	641611.4021	0.195289714	nonordnance	moderate	unknown	unknown	-99	-99		
7	88	4309739.7898	641623.5044	0.255378857	nonordnance	moderate	unknown	unknown	-99	-99		
7	89	4309739.3830	641631.7813	0.306178857	nonordnance	moderate	unknown	unknown	-99	-99		
7	96	4309701.6451	641650.2054	1.4478	nonordnance	moderate	unknown	unknown	-99	-99		
7	97	4309713.0544	641641.1070	0.5	nonordnance	moderate	unknown	unknown	-99	-99		empty hole
7	99	4309719.9596	641645.3574	0.361623429	nonordnance	moderate	unknown	unknown	-99	-99		
7	101	4309733.4743	641655.2261	0.376645714	nonordnance	moderate	unknown	unknown	-99	-99		
7	121	4309691.6496	641660.9546	0.462134857	nonordnance	moderate	unknown	unknown	-99	-99		
7	123	4309707.4266	641670.5189	0.361623429	nonordnance	moderate	unknown	unknown	-99	-99		
7	133	4309724.2303	641697.0443	0.618090857	nonordnance	moderate	unknown	unknown	-99	-99		
7	141	4309583.9011	641441.6773	0.537246286	nonordnance	moderate	unknown	unknown	-99	-99		
7	147	4309564.7999	641443.9335	0.406690286	nonordnance	moderate	unknown	unknown	-99	-99		
7	148	4309565.4019	641459.2680	0.481801714	nonordnance	moderate	unknown	unknown	-99	-99		
7	155	4309548.9508	641445.8415	0.075111429	nonordnance	moderate	unknown	unknown	-99	-99		
7	156	4309543.9401	641436.5504	0.210312	nonordnance	moderate	unknown	unknown	-99	-99		
7	158	4309535.2390	641432.6788	0.090133714	nonordnance	moderate	unknown	unknown	-99	-99		
7	159	4309540.5800	641449.2209	0.105156	nonordnance	moderate	unknown	unknown	-99	-99		
7	1	4309722.7032	641501.6964	0.351245714	nonordnance	high	unknown	unknown	-99	-99		
7	2	4309714.7198	641491.1256	0.370912571	nonordnance	high	unknown	unknown	-99	-99		
7	4	4309712.4513	641508.1419	0.225334286	nonordnance	high	unknown	unknown	-99	-99		
7	8	4309689.9635	641519.4151	0.745374545	nonordnance	high	unknown	unknown	-99	-99		
7	9	4309676.3815	641524.9589	0.692113714	nonordnance	high	unknown	unknown	-99	-99		
7	12	4309704.5973	641533.3263	0.345512571	nonordnance	high	unknown	unknown	-99	-99		
7	14	4309700.0305	641516.8877	0.676002857	nonordnance	high	unknown	unknown	-99	-99		
7	23	4309640.7573	641533.1100	0.526868571	nonordnance	high	unknown	unknown	-99	-99		
7	30	4309631.1377	641481.1569	0.768313714	nonordnance	high	unknown	unknown	-99	-99		
7	31	4309543.4536	641641.2868	0.394946909	nonordnance	high	unknown	unknown	-99	-99		
7	35	4309533.2889	641646.4195	0.477981818	nonordnance	high	unknown	unknown	-99	-99		
7	36	4309531.0660	641627.8857	0.535339636	nonordnance	high	unknown	unknown	-99	-99		
7	38	4309524.9229	641621.8741	0.248273455	nonordnance	high	unknown	unknown	-99	-99		
7	40	4309531.6078	641607.3828	0.114715636	nonordnance	high	unknown	unknown	-99	-99		
7	42	4309518.1664	641604.8853	0.286789091	nonordnance	high	unknown	unknown	-99	-99		
7	45	4309513.3141	641635.2695	0.305908364	nonordnance	high	unknown	unknown	-99	-99		
7	46	4309520.2743	641636.6327	0.210312	nonordnance	high	unknown	unknown	-99	-99		
7	48	4309511.7342	641648.6154	0.464866182	nonordnance	high	unknown	unknown	-99	-99		
7	49	4309505.2202	641641.0964	0.592143273	nonordnance	high	unknown	unknown	-99	-99		
7	52	4309493.9107	641651.4811	0.305631273	nonordnance	high	unknown	unknown	-99	-99		

7	54	4309488.6424	641658.9909	0.5	nonordnance	high	unknown	unknown	-99	-99		empty hole
7	56	4309478.6079	641677.0733	0.936567273	nonordnance	high	unknown	unknown	-99	-99		
7	59	4309492.0082	641680.9647	0.758213091	nonordnance	high	unknown	unknown	-99	-99		
7	62	4309517.9778	641669.5160	0.114715636	nonordnance	high	unknown	unknown	-99	-99		
7	63	4309526.9378	641666.1392	0.114715636	nonordnance	high	unknown	unknown	-99	-99		
7	64	4309538.8893	641668.4821	0.343869818	nonordnance	high	unknown	unknown	-99	-99		
7	65	4309547.0936	641676.5865	0.363266182	nonordnance	high	unknown	unknown	-99	-99		
7	67	4309537.0763	641680.9031	0.152954182	nonordnance	high	unknown	unknown	-99	-99		
7	73	4309732.6124	641580.4389	0.150222857	nonordnance	high	unknown	unknown	-99	-99		
7	74	4309750.9106	641571.3801	0.120178286	nonordnance	high	unknown	unknown	-99	-99		
7	85	4309737.7579	641607.0157	0.300445714	nonordnance	high	unknown	unknown	-99	-99		
7	91	4309731.8802	641636.3398	0.571935429	nonordnance	high	unknown	unknown	-99	-99		
7	102	4309740.6605	641646.0157	0.356978857	nonordnance	high	unknown	unknown	-99	-99		
7	103	4309749.1911	641637.0112	0.692113714	nonordnance	high	unknown	unknown	-99	-99		
7	105	4309736.6163	641672.7084	0.5	nonordnance	high	unknown	unknown	-99	-99		empty hole
7	108	4309737.9479	641686.8510	0.873469714	nonordnance	high	unknown	unknown	-99	-99		
7	110	4309721.7257	641673.2145	0.842336571	nonordnance	high	unknown	unknown	-99	-99		
7	112	4309717.4803	641654.6360	1.0668	nonordnance	high	unknown	unknown	-99	-99		
7	113	4309713.8929	641647.6050	0.150222857	nonordnance	high	unknown	unknown	-99	-99		
7	115	4309694.8690	641643.2166	0.180267429	nonordnance	high	unknown	unknown	-99	-99		
7	116	4309688.4696	641631.8135	0.127	nonordnance	high	unknown	unknown	-99	-99		
7	117	4309682.4102	641623.2747	0.617002286	nonordnance	high	unknown	unknown	-99	-99		
7	118	4309681.4582	641638.2797	0.271489714	nonordnance	high	unknown	unknown	-99	-99		
7	120	4309683.2732	641646.8557	0.376645714	nonordnance	high	unknown	unknown	-99	-99		
7	125	4309707.7725	641677.9689	0.300445714	nonordnance	high	unknown	unknown	-99	-99		
7	126	4309695.1010	641686.2686	0.360534857	nonordnance	high	unknown	unknown	-99	-99		
7	129	4309711.3264	641704.3392	0.270401143	nonordnance	high	unknown	unknown	-99	-99		
7	130	4309713.8164	641693.2683	0.542979429	nonordnance	high	unknown	unknown	-99	-99		
7	139	4309588.3687	641456.7064	0.837692	nonordnance	high	unknown	unknown	-99	-99		
7	143	4309575.8831	641458.8054	0.768313714	nonordnance	high	unknown	unknown	-99	-99		
7	149	4309557.2323	641460.6456	0.718602286	nonordnance	high	unknown	unknown	-99	-99		
7	150	4309556.9346	641450.1952	0.692113714	nonordnance	high	unknown	unknown	-99	-99		
7	152	4309557.9795	641426.6787	0.552268571	nonordnance	high	unknown	unknown	-99	-99		
7	153	4309551.5495	641418.8173	0.397401143	nonordnance	high	unknown	unknown	-99	-99		
7	154	4309552.5653	641432.4971	0.522224	nonordnance	high	unknown	unknown	-99	-99		
7	157	4309539.5701	641422.2841	0.165245143	nonordnance	high	unknown	unknown	-99	-99		

7	202	4309807.14	641579.38	0.345512571	ordnance	high	light	small	0	90	mortar	WES-2, 81-mm mortar
7	205	4309817.1	641578.44	0.51816	ordnance	high	moderate	medium	0	0	projectile	WES-5, 105-mm projectile
7	208	4309812.12	641578.91	0.751114286	ordnance	high	moderate	medium	90	0	projectile	WES-8, 155-mm projectile
7	201	4309865.25	641598.98	0.057357818	nonordnance	high	unknown	unknown	-99	-99		WES-1
7	203	4309820.64	641615.77	0.5	nonordnance	high	unknown	unknown	-99	-99		WES-3, empty hole
7	204	4309799.18	641580.14	0.330490286	nonordnance	high	unknown	unknown	-99	-99		WES-4
7	206	4309807.66	641584.86	0.994202182	nonordnance	high	unknown	unknown	-99	-99		WES-6
7	207	4309880.06	641622.68	0.038238545	nonordnance	high	unknown	unknown	-99	-99		WES-7
7	209	4309812.64	641584.38	0.630936	nonordnance	high	unknown	unknown	-99	-99		WES-9
7	210	4309791.73	641586.37	0.045066857	nonordnance	high	unknown	unknown	-99	-99		WES-10



%TP = (Correct Ordnance Declarations / TOB) x 100

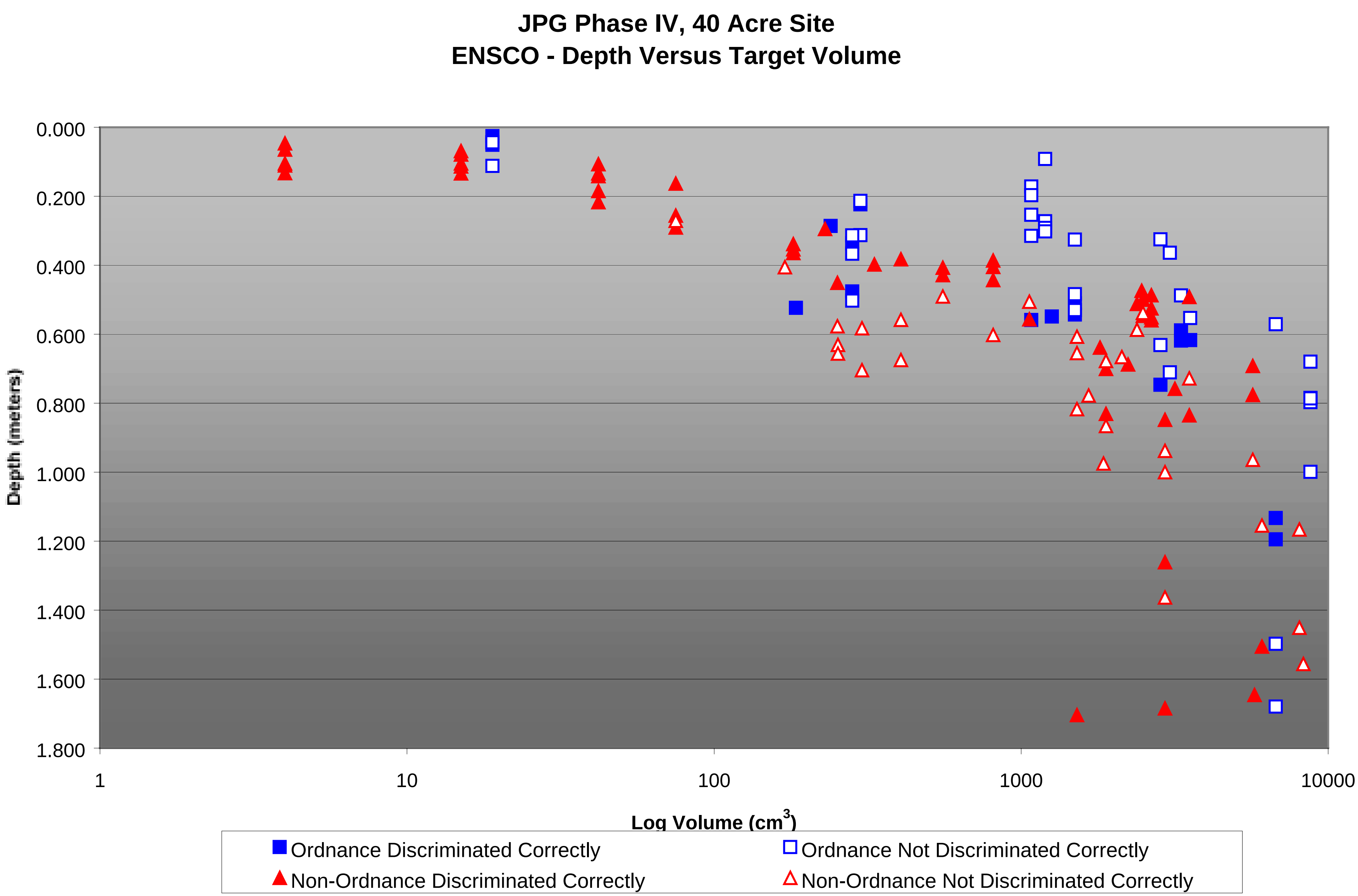
%TN = (Correct Non-Ordnance Declarations / TNOB) x 100

%FP = (Non-Ordnance Declared as Ordnance / TNOB) x 100

%Ou = (Ordnance Declared as Unknown / TOB) x 100

%Nu = (Non-Ordnance Declared as Unknown / TNOB) x 100

%FN = (Ordnance Declared as Non-Ordnance / TOB) x 100



25 Targets missing from the Non-Ordnance Baseline

Geophex

rank	target	northing	easting	depth	type	confidence	weight	size	az.	dec.	class	comments
1	5	4309699.31	641487.30	0.19	ordnance	high	light	small	135	45	p	20mm, small pipe (cl-3)
2	72	4309741.85	641580.80	0.12	ordnance	high	light	small	45	45	p	20mm, pipe+washer (cl-3)
3	33	4309536.12	641637.05	0.19	ordnance	high	light	small	135	45	p	20mm, small tube (cl-3)
4	155	4309548.95	641445.84	0.20	ordnance	high	light	small	90	0	p	20mm
5	80	4309724.92	641583.68	0.35	ordnance	high	light	small	45	0	p	57mm, 60mm
6	3	4309723.49	641489.96	0.37	ordnance	high	light	small	90	45	m	81mm
7	61	4309511.17	641664.40	0.40	ordnance	high	light	small	135	0	m	60mm, 57mm
8	52	4309493.91	641651.48	0.46	ordnance	high	moderate	medium	90	45	p	105mm
9	47	4309518.96	641646.01	0.47	ordnance	high	light	small	0	0	m	81mm
10	154	4309552.57	641432.50	0.55	ordnance	high	light	small	90	0	p	90mm
11	57	4309487.49	641674.04	0.65	ordnance	high	moderate	medium	135	45	p	4.2", 90mm
12	22	4309648.86	641528.65	0.68	ordnance	high	moderate	medium	0	0	p	105mm, 81mm
13	99	4309719.96	641645.36	0.41	ordnance	moderate	moderate	medium	90	0	m	4.2", 90mm
14	113	4309713.89	641647.61	0.20	ordnance	moderate	light	small	90	45	p	20mm, pipe+washer (cl-3)
15	74	4309750.91	641571.38	0.25	ordnance	moderate	light	small	45	0	p	20mm, small tube (cl-3)
16	88	4309739.79	641623.50	0.30	ordnance	moderate	light	small	135	0	m	60mm, 81mm illum
17	46	4309520.27	641636.63	0.32	ordnance	moderate	light	small	45	0	m	81mm, 60mm
18	17	4309666.50	641517.38	0.33	ordnance	moderate	light	small	45	0	m	60mm, 81mm, 76mm
19	67	4309537.08	641680.90	0.39	ordnance	moderate	light	small	90	0	m	81 illum, 76mm
20	81	4309715.75	641601.88	0.40	ordnance	moderate	light	small	135	45	m	60mm, 57mm
21	31	4309543.45	641641.29	0.42	ordnance	moderate	moderate	medium	135	45	p	105mm, 155mm, 90mm
22	39	4309517.60	641625.27	0.45	ordnance	moderate	light	small	135	45	p	57mm, 60mm
23	64	4309538.89	641668.48	0.45	ordnance	moderate	light	small	0	0	m	81mm, 76mm, pipes (cl-15)
24	89	4309739.38	641631.78	0.45	ordnance	moderate	light	small	0	0	m	81mm
25	79	4309723.15	641592.11	0.48	ordnance	moderate	moderate	medium	45	45	p	105mm
26	153	4309551.55	641418.82	0.52	ordnance	moderate	moderate	medium	90	45	m	4.2", 152mm
27	23	4309640.76	641533.11	0.58	ordnance	moderate	moderate	medium	135	45	p	105 HEAT, 81mm, 4.2"
28	49	4309505.22	641641.10	0.62	ordnance	moderate	light	small	45	45	p	90mm, 4.2"
29	48	4309511.73	641648.62	0.64	ordnance	moderate	moderate	medium	0	0	p	105mm, 152mm, ibar
30	35	4309533.29	641646.42	0.65	ordnance	moderate	moderate	medium	0	45	p	105mm, 81mm
31	142	4309581.78	641450.06	0.69	ordnance	moderate	moderate	medium	0	0	p	105mm
32	148	4309565.40	641459.27	0.70	ordnance	moderate	moderate	medium	45	45	p	105 HEAT, 155mm
33	151	4309559.19	641438.97	0.70	ordnance	moderate	moderate	medium	0	0	p	105 HEAT, 152mm
34	150	4309556.93	641450.20	0.83	ordnance	moderate	moderate	medium	45	0	p	105 HEAT, 152mm
35	120	4309683.27	641646.86	0.65	ordnance	moderate	moderate	medium	0	45	p	105 HEAT, 90mm, 81mm
36	8	4309689.96	641519.42	0.86	ordnance	moderate	moderate	medium	135	45	p	105 HEAT
37	27	4309637.33	641494.33	0.61	ordnance	moderate	moderate	medium	0	0	p	152mm, 4.2", 152mm, 90mm
38	145	4309571.70	641434.74	0.43	ordnance	low	light	small	45	0	m	60mm, 57mm, ibar (cl-7)
39	146	4309566.49	641426.01	0.60	ordnance	low	light	small	0	0	m	81mm illum (aluminum)
40	65	4309547.09	641676.59	0.44	ordnance	low	light	small	45	0	m	81mm, 76mm, 60mm
41	123	4309707.43	641670.52	0.51	ordnance	low	light	small	45	0	m	81mm, 60mm
42	125	4309707.77	641677.97	0.55	ordnance	low	light	small	135	45	m	81mm, pipe (cl-15), ibar (cl-8)
43	138	4309591.08	641465.64	0.60	ordnance	low	moderate	medium	0	0	p	105mm
44	131	4309718.27	641687.11	0.61	ordnance	low	moderate	small	135	0	p	105mm, 81mmillum, 4.2"
45	98	4309720.18	641636.30	0.65	ordnance	low	moderate	medium	90	0	p	105 HEAT
46	101	4309733.47	641655.23	0.70	ordnance	low	moderate	medium	0	0	p	105 HEAT, 155mm
47	141	4309583.90	641441.68	0.70	ordnance	low	moderate	medium	45	45	p	105mm, 90mm
48	152	4309557.98	641426.68	0.72	ordnance	low	moderate	medium	0	0	m	4.2", 105 HEAT
49	91	4309731.88	641636.34	0.52	ordnance	low	moderate	medium	0	45	p	90mm, 105mm
50	90	4309731.48	641627.13	1.20	ordnance	low	moderate	medium	0	0	p	152mm, pipes+plates (?)
51	129	4309711.33	641704.34	0.40	ordnance	low	light	small	0	45	m	81mm, ibar (cl-7)
52	140	4309588.10	641447.88	1.24	ordnance	low	moderate	medium	90	45	p	155mm
53	93	4309713.13	641626.89	1.60	ordnance	low	moderate	medium	0	0	p	155mm, 152mm
54	104	4309746.15	641659.91	0.95	ordnance	low	moderate	medium	0	90	p	155mm, 152mm
55	108	4309737.95	641686.85	1.10	ordnance	low	moderate	medium	135	0	p	155mm, 152mm
56	68	4309530.70	641686.63	0.30	nonordnance	low	light	-99	-99	-99		unknown, 57mm (?)
57	21	4309647.79	641513.14	0.58	nonordnance	low	light	-99	-99	-99		pipe+plate (cl-21), 81mm
58	19	4309660.16	641525.29	0.70	nonordnance	low	light	-99	-99	-99		ibar, 81mm
59	15	4309698.16	641541.13	0.84	nonordnance	low	moderate	-99	-99	-99		ibar (cl-7), 81mm
60	9	4309676.38	641524.96	0.86	nonordnance	low	light	-99	-99	-99		c-channel (cl-27), 81mm
61	109	4309737.30	641680.23	2.10	nonordnance	low	moderate	-99	-99	-99		unknown

62	105	4309736.62	641672.71	1.90	nonordnance	low	moderate	-99	-99	-99		unknown
63	112	4309717.48	641654.64	1.85	nonordnance	low	moderate	-99	-99	-99		unknown
64	16	4309685.35	641538.48	1.83	nonordnance	low	moderate	-99	-99	-99		unknown
65	54	4309488.64	641658.99	1.80	nonordnance	low	moderate	-99	-99	-99		unknown
66	28	4309648.35	641480.08	1.61	nonordnance	low	moderate	-99	-99	-99		unknown
67	29	4309639.57	641477.01	1.60	nonordnance	low	moderate	-99	-99	-99		unknown
68	106	4309744.70	641680.61	1.60	nonordnance	low	moderate	-99	-99	-99		unknown
69	107	4309743.43	641695.05	1.60	nonordnance	low	moderate	-99	-99	-99		unknown
70	51	4309491.99	641640.43	1.55	nonordnance	low	moderate	-99	-99	-99		152mm (?)
71	53	4309502.13	641654.46	1.50	nonordnance	low	moderate	-99	-99	-99		155mm (?)
72	24	4309633.70	641524.66	1.23	nonordnance	low	moderate	-99	-99	-99		unknown
73	58	4309485.96	641684.15	1.00	nonordnance	low	moderate	-99	-99	-99		unknown
74	114	4309699.44	641657.94	1.00	nonordnance	low	moderate	-99	-99	-99		unknown
75	124	4309716.36	641670.84	1.00	nonordnance	low	moderate	-99	-99	-99		c-channel (cl-33)
76	78	4309731.32	641596.01	0.95	nonordnance	low	moderate	-99	-99	-99		unknown
77	11	4309711.92	641524.55	0.85	nonordnance	low	moderate	-99	-99	-99		unknown target
78	14	4309700.03	641516.89	0.75	nonordnance	low	moderate	-99	-99	-99		unknown
79	92	4309721.19	641626.86	1.70	nonordnance	low	moderate	-99	-99	-99		plate stack (cl-36)
80	128	4309706.08	641696.89	0.63	nonordnance	low	light	-99	-99	-99		unknown
81	110	4309721.73	641673.21	1.00	nonordnance	low	moderate	-99	-99	-99		plate
82	83	4309721.05	641611.78	0.43	nonordnance	low	light	-99	-99	-99		unknown
83	40	4309531.61	641607.38	0.28	nonordnance	low	light	-99	-99	-99		unknown
84	126	4309695.10	641686.27	0.65	nonordnance	low	light	-99	-99	-99		plate stack
85	30	4309631.14	641481.16	0.73	nonordnance	low	moderate	-99	-99	-99		plate (cl-25), pipe (cl-34)
86	10	4309671.29	641533.85	1.80	nonordnance	low	moderate	-99	-99	-99		plate stack (cl-37)
87	127	4309707.40	641689.42	0.75	nonordnance	low	moderate	-99	-99	-99		plate stack (cl-27, 28)
88	103	4309749.19	641637.01	0.92	nonordnance	low	moderate	-99	-99	-99		pipes+plates (cl-33)
89	139	4309588.37	641456.71	0.95	nonordnance	low	moderate	-99	-99	-99		plate (cl-24, 25)
90	132	4309726.26	641690.09	0.80	nonordnance	low	moderate	-99	-99	-99		plate stack
91	25	4309647.94	641494.91	0.75	nonordnance	low	light	-99	-99	-99		plate (cl-23, 27)
92	41	4309525.66	641610.30	0.74	nonordnance	low	light	-99	-99	-99		plate (cl-9)
93	135	4309725.58	641705.75	0.99	nonordnance	low	moderate	-99	-99	-99		plate stack
94	100	4309724.72	641654.05	0.61	nonordnance	low	light	-99	-99	-99		plate
95	118	4309681.46	641638.28	0.95	nonordnance	low	moderate	-99	-99	-99		plate (cl-9, 11)
96	77	4309738.56	641594.20	1.05	nonordnance	low	light	-99	-99	-99		plates (cl-9)
97	136	4309732.42	641703.43	1.00	nonordnance	low	moderate	-99	-99	-99		plate stack
98	119	4309674.72	641644.17	0.63	nonordnance	low	light	-99	-99	-99		plate
99	94	4309710.07	641634.08	1.40	nonordnance	low	moderate	-99	-99	-99		plate stack (cl-37)
100	32	4309539.57	641651.14	1.08	nonordnance	low	moderate	-99	-99	-99		plate stack (cl-20, 21)
101	20	4309656.01	641500.36	0.37	nonordnance	low	light	-99	-99	-99		plate, 60mm
102	75	4309753.53	641588.17	0.22	nonordnance	low	light	-99	-99	-99		single disk (cl-1)
103	2	4309714.72	641491.13	0.69	nonordnance	moderate	moderate	-99	-99	-99		c-channel (cl-27)
104	87	4309752.12	641611.40	0.58	nonordnance	moderate	light	-99	-99	-99		ibar (cl-7)
105	4	4309712.45	641508.14	0.41	nonordnance	moderate	light	-99	-99	-99		ibar, 60mm
106	96	4309701.65	641650.21	1.70	nonordnance	moderate	moderate	-99	-99	-99		unknown
107	97	4309713.05	641641.11	1.70	nonordnance	moderate	moderate	-99	-99	-99		unknown
108	56	4309478.61	641677.07	1.10	nonordnance	moderate	moderate	-99	-99	-99		rect plates (cl-25)
109	122	4309699.04	641666.67	0.93	nonordnance	moderate	moderate	-99	-99	-99		plate (cl-22)
110	59	4309492.01	641680.96	0.85	nonordnance	moderate	light	-99	-99	-99		plate (cl-22)
111	95	4309696.28	641636.28	0.85	nonordnance	moderate	moderate	-99	-99	-99		rect plate stack
112	111	4309721.85	641661.97	0.85	nonordnance	moderate	moderate	-99	-99	-99		plate (cl-24, 25)
113	160	4309533.94	641457.34	0.78	nonordnance	moderate	moderate	-99	-99	-99		rect plate, c-channel
114	149	4309557.23	641460.65	0.75	nonordnance	moderate	moderate	-99	-99	-99		plate stack (cl-34, 37)
115	84	4309730.05	641610.97	0.70	nonordnance	moderate	light	-99	-99	-99		plate (cl-11)
116	133	4309724.23	641697.04	0.70	nonordnance	moderate	moderate	-99	-99	-99		rect plates (cl-24)
117	130	4309713.82	641693.27	0.47	nonordnance	moderate	light	-99	-99	-99		plates welded (cl-17)
118	36	4309531.07	641627.89	0.67	nonordnance	moderate	moderate	-99	-99	-99		plate (cl-12), c-channel
119	137	4309738.07	641699.60	0.67	nonordnance	moderate	moderate	-99	-99	-99		plate (cl-24)
120	1	4309722.70	641501.70	0.56	nonordnance	moderate	light	-99	-99	-99		plate stack (cl-20, 21)
121	121	4309691.65	641660.95	0.55	nonordnance	moderate	light	-99	-99	-99		plates+pipes (cl-9,12)
122	86	4309745.25	641608.31	0.45	nonordnance	moderate	light	-99	-99	-99		plate (cl-9, 12)
123	63	4309526.94	641666.14	0.30	nonordnance	moderate	light	-99	-99	-99		welded pipes (cl-15), 81mm
124	159	4309540.58	641449.22	0.27	nonordnance	moderate	light	-99	-99	-99		tube+washer (cl-3), 20mm
125	157	4309539.57	641422.28	0.25	nonordnance	moderate	light	-99	-99	-99		small tube (cl-3)

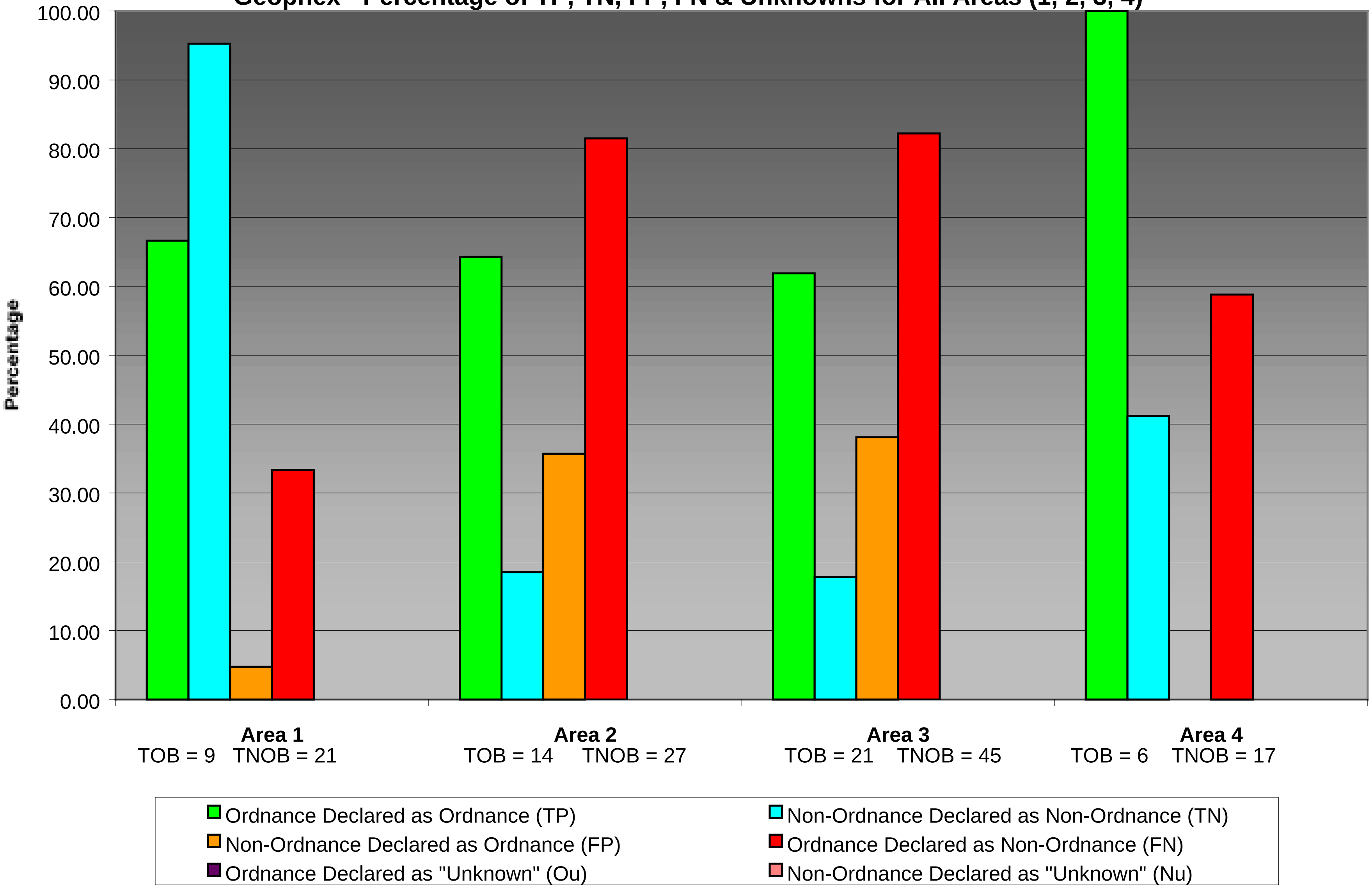
126	158	4309535.24	641432.68	0.25	nonordnance	moderate	light	-99	-99	-99		single disk (cl-1)
127	117	4309682.41	641623.27	0.88	nonordnance	moderate	moderate	-99	-99	-99		rect tubes (cl-31, 36)
128	62	4309517.98	641669.52	0.14	nonordnance	moderate	light	-99	-99	-99		plate
129	134	4309719.03	641703.26	1.00	nonordnance	high	moderate	-99	-99	-99		rect plate
130	76	4309745.94	641596.09	0.75	nonordnance	high	moderate	-99	-99	-99		c-channel (cl-33)
131	60	4309497.79	641670.67	0.67	nonordnance	high	light	-99	-99	-99		plates (cl-12)
132	66	4309543.17	641685.24	0.66	nonordnance	high	moderate	-99	-99	-99		crossed plates (cl-12, 22)
133	55	4309481.43	641663.30	0.60	nonordnance	high	light	-99	-99	-99		plate stack (cl-12, 22)
134	70	4309521.63	641686.13	0.60	nonordnance	high	light	-99	-99	-99		crossed plates (cl-12)
135	143	4309575.88	641458.81	0.60	nonordnance	high	moderate	-99	-99	-99		rect tubes+plate (cl-36)
136	50	4309500.51	641633.49	0.57	nonordnance	high	light	-99	-99	-99		crossed plates (cl-12)
137	45	4309513.31	641635.27	0.56	nonordnance	high	light	-99	-99	-99		ibar (cl-7, 8)
138	12	4309704.60	641533.33	0.51	nonordnance	high	light	-99	-99	-99		plates (cl-12, 22)
139	82	4309712.38	641610.36	0.51	nonordnance	high	moderate	-99	-99	-99		rect plate stack (cl-24)
140	44	4309506.92	641625.36	0.50	nonordnance	high	light	-99	-99	-99		plates (cl-9, 10, 11, 12)
141	69	4309529.65	641675.59	0.48	nonordnance	high	light	-99	-99	-99		crossed plates (cl-12)
142	43	4309512.93	641612.77	0.45	nonordnance	high	light	-99	-99	-99		square plate (cl-4)
143	85	4309737.76	641607.02	0.42	nonordnance	high	light	-99	-99	-99		crossed plates (cl-12, 22)
144	144	4309576.94	641442.02	0.40	nonordnance	high	light	-99	-99	-99		plate
145	42	4309518.17	641604.89	0.39	nonordnance	high	light	-99	-99	-99		ibar (cl-5, 6, 7)
146	71	4309511.26	641685.85	0.39	nonordnance	high	light	-99	-99	-99		single plate (cl-4)
147	18	4309662.06	641508.74	0.34	nonordnance	high	light	-99	-99	-99		ibar (cl-7)
148	147	4309564.80	641443.93	0.30	nonordnance	high	light	-99	-99	-99		ibar (cl-7)
149	26	4309636.74	641511.68	0.27	nonordnance	high	light	-99	-99	-99		rect plate (cl-22)
150	37	4309527.77	641639.37	0.20	nonordnance	high	light	-99	-99	-99		small disk (cl-2, 3)
151	38	4309524.92	641621.87	0.20	nonordnance	high	light	-99	-99	-99		small tube (cl-3), 20mm
152	34	4309542.76	641627.66	0.19	nonordnance	high	light	-99	-99	-99		single disk (cl-1, 2)
153	13	4309684.84	641503.19	0.30	nonordnance	high	light	-99	-99	-99		single disk (cl-1, 2)
154	73	4309732.61	641580.44	0.14	nonordnance	high	light	-99	-99	-99		single disk (cl-1)
155	102	4309740.66	641646.02	0.36	nonordnance	high	moderate	-99	-99	-99		plate (cl-22, 12)
156	156	4309543.94	641436.55	0.35	nonordnance	high	light	-99	-99	-99		small disk (cl-2, 3)
157	6	4309707.48	641478.93	0.14	nonordnance	high	light	-99	-99	-99		disks (cl-2), 20mm
158	7	4309695.31	641497.25	0.30	nonordnance	high	light	-99	-99	-99		pipe+washer (cl-3)
159	116	4309688.47	641631.81	0.17	nonordnance	high	light	-99	-99	-99		single disk (cl-1)
160	115	4309694.87	641643.22	0.12	nonordnance	high	light	-99	-99	-99		disks (cl-2,1)

* The designators in the CLASS column are: p = projectile; m = mortar

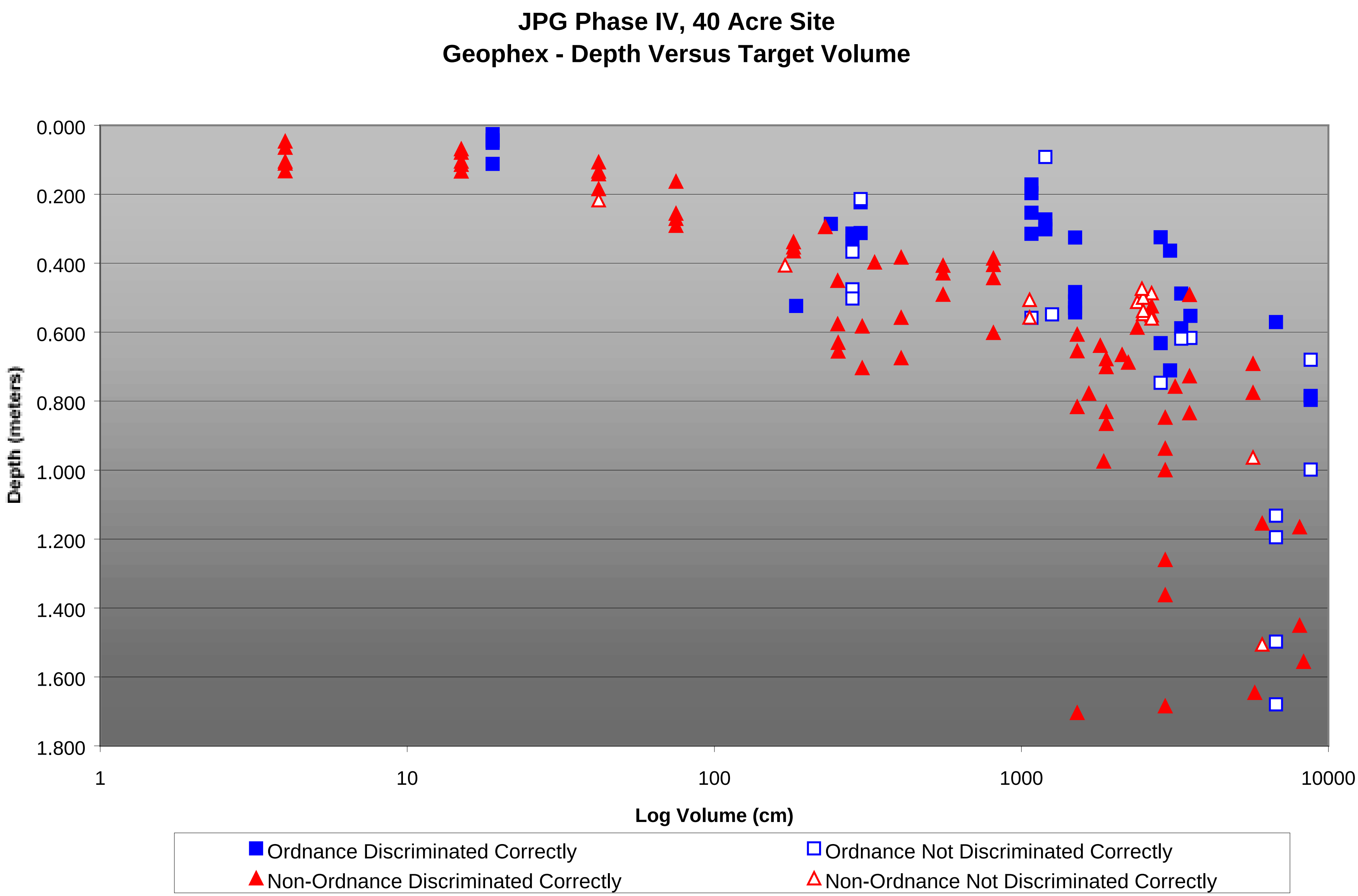
** "cl-#" refers to a particular clutter item as designated by Geophex

*** Rank column: 1 is "most likely UXO" and 160 is "least likely UXO"

JPG Phase IV, 40 Acre Site
Geophex - Percentage of TP, TN, FP, FN & Unknowns for All Areas (1, 2, 3, 4)



%TP = (Correct Ordnance Declarations / TOB) x 100
%TN = (Correct Non-Ordnance Declarations / TNOB) x 100
%FP = (Non-Ordnance Declared as Ordnance / TNOB) x 100
%Ou = (Ordnance Declared as Unknown / TOB) x 100
%Nu = (Non-Ordnance Declared as Unknown / TNOB) x 100
%FN = (Ordnance Declared as Non-Ordnance / TOB) x 100



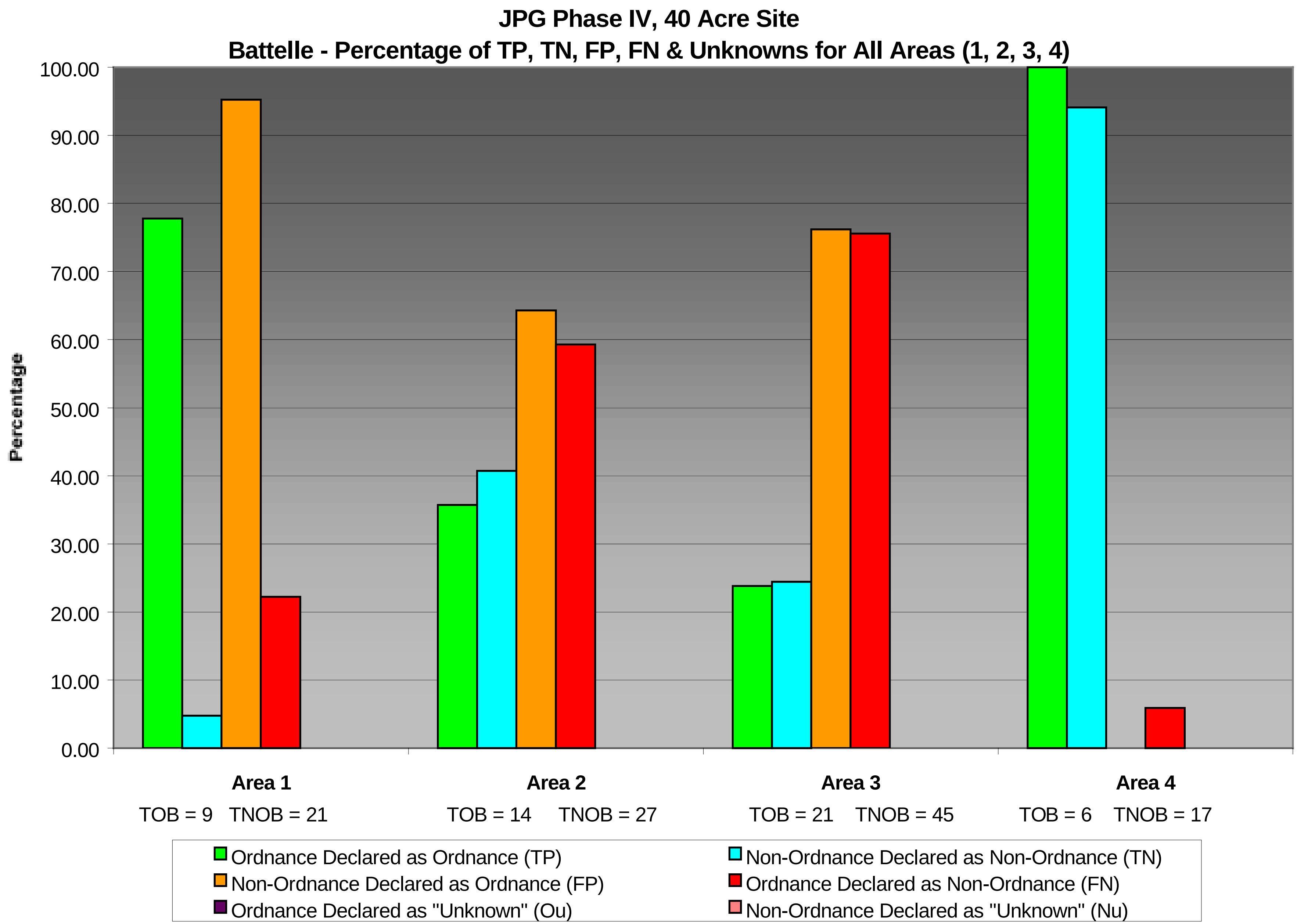
25 Targets missing from the Non-Ordnance Baseline

Battelle

demonstrator	target	northing	easting	depth	type	confidence	weight	size	azimuth (see Note 1)	declination	class	comments (See Note 2)
BAT	1	4309722.70	641501.70	0.26	**ordnance**	high	unknown	unknown	304	-99	unknown	0.61
BAT	5	4309699.31	641487.30	0.52	**ordnance**	high	unknown	unknown	351	-99	unknown	0.77,0.56
BAT	6	4309707.48	641478.93	0.68	**ordnance**	high	unknown	unknown	326	-99	unknown	0.65,0.49
BAT	7	4309695.31	641497.25	0.53	**ordnance**	high	unknown	unknown	348	-99	unknown	0.58
BAT	11	4309711.92	641524.55	0.38	**ordnance**	high	unknown	unknown	359	-99	unknown	0.63,0.45
BAT	14	4309700.03	641516.89	0.77	**ordnance**	high	unknown	unknown	301	-99	unknown	0.62
BAT	18	4309662.06	641508.74	0.31	**ordnance**	high	unknown	unknown	275	-99	unknown	0.61
BAT	21	4309647.79	641513.14	0.55	**ordnance**	high	unknown	unknown	302	-99	unknown	1
BAT	26	4309636.74	641511.68	0.55	**ordnance**	high	unknown	unknown	358	-99	unknown	0.84
BAT	34	4309542.76	641627.66	0.25	**ordnance**	high	unknown	unknown	307	-99	unknown	0.67,0.38
BAT	39	4309517.60	641625.27	0.45	**ordnance**	high	unknown	unknown	282	-99	unknown	0.68
BAT	43	4309512.93	641612.77	0.46	**ordnance**	high	unknown	unknown	349	-99	unknown	0.87
BAT	44	4309506.92	641625.36	0.51	**ordnance**	high	unknown	unknown	320	-99	unknown	0.82
BAT	47	4309518.96	641646.01	0.37	**ordnance**	high	unknown	unknown	328	-99	unknown	0.85
BAT	50	4309500.51	641633.49	0.58	**ordnance**	high	unknown	unknown	356	-99	unknown	0.55
BAT	52	4309493.91	641651.48	0.63	**ordnance**	high	unknown	unknown	333	-99	unknown	0.77
BAT	81	4309715.75	641601.88	0.49	**ordnance**	high	unknown	unknown	352	-99	unknown	0.61
BAT	88	4309739.79	641623.50	0.34	**ordnance**	high	unknown	unknown	277	-99	unknown	0.58,0.41
BAT	95	4309696.28	641636.28	0.43	**ordnance**	high	unknown	unknown	297	-99	unknown	0.72
BAT	115	4309694.87	641643.22	0.62	**ordnance**	high	unknown	unknown	309	-99	unknown	0.64
BAT	116	4309688.47	641631.81	0.66	**ordnance**	high	unknown	unknown	352	-99	unknown	0.69,0.45
BAT	129	4309711.33	641704.34	0.41	**ordnance**	high	unknown	unknown	320	-99	unknown	0.34
BAT	130	4309713.82	641693.27	0.49	**ordnance**	high	unknown	unknown	289	-99	unknown	1.03
BAT	134	4309719.03	641703.26	0.79	**ordnance**	high	unknown	unknown	357	-99	unknown	0.5
BAT	135	4309725.58	641705.75	0.6	**ordnance**	high	unknown	unknown	291	-99	unknown	0.58
BAT	136	4309732.42	641703.43	0.31	**ordnance**	high	unknown	unknown	338	-99	unknown	0.66,0.51
BAT	138	4309591.08	641465.64	0.54	**ordnance**	high	unknown	unknown	300	-99	unknown	0.54
BAT	139	4309588.37	641456.71	1	**ordnance**	high	unknown	unknown	309	-99	unknown	0.58
BAT	144	4309576.94	641442.02	1.02	**ordnance**	high	unknown	unknown	287	-99	unknown	0.3
BAT	145	4309571.70	641434.74	0.34	**ordnance**	high	unknown	unknown	290	-99	unknown	0.62,0.39
BAT	146	4309566.49	641426.01	0.36	**ordnance**	high	unknown	unknown	292	-99	unknown	0.73,0.50
BAT	147	4309564.80	641443.93	0.54	**ordnance**	high	unknown	unknown	337	-99	unknown	0.3
BAT	151	4309559.19	641438.97	0.64	**ordnance**	high	unknown	unknown	302	-99	unknown	0.56,0.41
BAT	153	4309551.55	641418.82	0.43	**ordnance**	high	unknown	unknown	353	-99	unknown	0.66,0.39
BAT	155	4309548.95	641445.84	0.92	**ordnance**	high	unknown	unknown	351	-99	unknown	0.49
BAT	156	4309543.94	641436.55	0.69	**ordnance**	high	unknown	unknown	294	-99	unknown	0.54
BAT	158	4309535.24	641432.68	0.5	**ordnance**	high	unknown	unknown	350	-99	unknown	0.68,0.49
BAT	2	4309714.72	641491.13	0.78	**ordnance**	moderate	unknown	unknown	276	-99	unknown	0.55
BAT	3	4309723.49	641489.96	0.51	**ordnance**	moderate	unknown	unknown	270	-99	unknown	0.79
BAT	4	4309712.45	641508.14	0.37	**ordnance**	moderate	unknown	unknown	349	-99	unknown	0.47
BAT	9	4309676.38	641524.96	0.38	**ordnance**	moderate	unknown	unknown	322	-99	unknown	0.91,0.64
BAT	10	4309671.29	641533.85	0.49	**ordnance**	moderate	unknown	unknown	355	-99	unknown	0.44
BAT	13	4309684.84	641503.19	0.39	**ordnance**	moderate	unknown	unknown	310	-99	unknown	0.67,0.54
BAT	15	4309698.16	641541.13	0.25	**ordnance**	moderate	unknown	unknown	298	-99	unknown	0.6
BAT	17	4309666.50	641517.38	0.29	**ordnance**	moderate	unknown	unknown	276	-99	unknown	0.31
BAT	20	4309656.01	641500.36	0.39	**ordnance**	moderate	unknown	unknown	280	-99	unknown	0.7
BAT	22	4309648.86	641528.65	0.55	**ordnance**	moderate	unknown	unknown	289	-99	unknown	0.85
BAT	23	4309640.76	641533.11	0.44	**ordnance**	moderate	unknown	unknown	341	-99	unknown	0.58
BAT	24	4309633.70	641524.66	0.45	**ordnance**	moderate	unknown	unknown	297	-99	unknown	0.69
BAT	28	4309648.35	641480.08	0.47	**ordnance**	moderate	unknown	unknown	309	-99	unknown	0.3
BAT	38	4309524.92	641621.87	0.16	**ordnance**	moderate	unknown	unknown	287	-99	unknown	0.70,0.50
BAT	40	4309531.61	641607.38	0.53	**ordnance**	moderate	unknown	unknown	346	-99	unknown	0.67,0.41
BAT	42	4309518.17	641604.89	0.47	**ordnance**	moderate	unknown	unknown	309	-99	unknown	0.84,0.31
BAT	49	4309505.22	641641.10	0.46	**ordnance**	moderate	unknown	unknown	331	-99	unknown	0.72,0.37
BAT	54	4309488.64	641658.99	0.43	**ordnance**	moderate	unknown	unknown	354	-99	unknown	0.37
BAT	55	4309481.43	641663.30	0.55	**ordnance**	moderate	unknown	unknown	355	-99	unknown	0.40,0.31
BAT	65	4309547.09	641676.59	0.56	**ordnance**	moderate	unknown	unknown	337	-99	unknown	0.47
BAT	82	4309712.38	641610.36	0.64	**ordnance**	moderate	unknown	unknown	321	-99	unknown	0.82
BAT	87	4309752.12	641611.40	0.33	**ordnance**	moderate	unknown	unknown	303	-99	unknown	0.61
BAT	137	4309738.07	641699.60	0.77	**ordnance**	moderate	unknown	unknown	354	-99	unknown	0.96
BAT	140	4309588.10	641447.88	0.42	**ordnance**	moderate	unknown	unknown	334	-99	unknown	0.44

BAT	149	4309557.23	641460.65	0.55	**ordnance**	moderate	unknown	unknown	295	-99	unknown	0.56
BAT	152	4309557.98	641426.68	0.79	**ordnance**	moderate	unknown	unknown	283	-99	unknown	0.66,0.50
BAT	157	4309539.57	641422.28	0.44	**ordnance**	moderate	unknown	unknown	306	-99	unknown	0.48,0.29
BAT	159	4309540.58	641449.22	0.32	**ordnance**	moderate	unknown	unknown	327	-99	unknown	0.59
BAT	**E3**	4309820.64	641615.77	**0.56**	**ordnance**	moderate	unknown	unknown	309	-99	unknown	**0.72**
BAT	**E4**	4309799.18	641580.14	**0.44**	**ordnance**	moderate	unknown	unknown	359	-99	unknown	**0.82**
BAT	**E6**	4309807.66	641584.86	**0.29**	**ordnance**	moderate	unknown	unknown	304	-99	unknown	0.64
BAT	**E9**	4309812.64	641584.38	**0.89**	**ordnance**	moderate	unknown	unknown	266	-99	unknown	**0.82**
BAT	16	4309685.35	641538.48	0.52	**ordnance**	low	unknown	unknown	340	-99	unknown	0.93
BAT	19	4309660.16	641525.29	0.59	**ordnance**	low	unknown	unknown	284	-99	unknown	0.65
BAT	25	4309647.94	641494.91	0.67	**ordnance**	low	unknown	unknown	277	-99	unknown	0.54
BAT	29	4309639.57	641477.01	0.57	**ordnance**	low	unknown	unknown	355	-99	unknown	0.67
BAT	30	4309631.14	641481.16	0.73	**ordnance**	low	unknown	unknown	327	-99	unknown	0.39
BAT	46	4309520.27	641636.63	0.32	**ordnance**	low	unknown	unknown	284	-99	unknown	0.6
BAT	69	4309529.65	641675.59	0.61	**ordnance**	low	unknown	unknown	315	-99	unknown	0.52
BAT	92	4309721.19	641626.86	0.58	**ordnance**	low	unknown	unknown	295	-99	unknown	0.72
BAT	99	4309719.96	641645.36	0.43	**ordnance**	low	unknown	unknown	290	-99	unknown	0.57
BAT	131	4309718.27	641687.11	0.5	**ordnance**	low	unknown	unknown	348	-99	unknown	0.8
BAT	141	4309583.90	641441.68	0.57	**ordnance**	low	unknown	unknown	311	-99	unknown	0.38
BAT	142	4309581.78	641450.06	0.47	**ordnance**	low	unknown	unknown	276	-99	unknown	0.62
BAT	143	4309575.88	641458.81	0.81	**ordnance**	low	unknown	unknown	332	-99	unknown	0.24
BAT	148	4309565.40	641459.27	0.83	**ordnance**	low	unknown	unknown	312	-99	unknown	0.54
BAT	154	4309552.57	641432.50	0.45	**ordnance**	low	unknown	unknown	328	-99	unknown	0.60,0.45
BAT	160	4309533.94	641457.34	0.57	**ordnance**	low	unknown	unknown	294	-99	unknown	0.6
BAT	**E7**	4309880.06	641622.68	**0.75**	**ordnance**	low	unknown	unknown	359	-99	unknown	**1.21**
BAT	8	4309689.96	641519.42	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	12	4309704.60	641533.33	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	27	4309637.33	641494.33	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	31	4309543.45	641641.29	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	32	4309539.57	641651.14	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	33	4309536.12	641637.05	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	35	4309533.29	641646.42	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	36	4309531.07	641627.89	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	37	4309527.77	641639.37	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	41	4309525.66	641610.30	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	45	4309513.31	641635.27	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	48	4309511.73	641648.62	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	51	4309491.99	641640.43	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	53	4309502.13	641654.46	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	56	4309478.61	641677.07	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	57	4309487.49	641674.04	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	58	4309485.96	641684.15	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	59	4309492.01	641680.96	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	60	4309497.79	641670.67	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	61	4309511.17	641664.40	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	62	4309517.98	641669.52	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	63	4309526.94	641666.14	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	64	4309538.89	641668.48	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	66	4309543.17	641685.24	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	67	4309537.08	641680.90	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	68	4309530.70	641686.63	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	70	4309521.63	641686.13	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	71	4309511.26	641685.85	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	72	4309741.85	641580.80	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	73	4309732.61	641580.44	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	74	4309750.91	641571.38	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	75	4309753.53	641588.17	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	76	4309745.94	641596.09	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	77	4309738.56	641594.20	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	78	4309731.32	641596.01	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	79	4309723.15	641592.11	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	80	4309724.92	641583.68	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	83	4309721.05	641611.78	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	84	4309730.05	641610.97	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	

BAT	85	4309737.76	641607.02	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	86	4309745.25	641608.31	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	89	4309739.38	641631.78	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	90	4309731.48	641627.13	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	91	4309731.88	641636.34	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	93	4309713.13	641626.89	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	94	4309710.07	641634.08	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	96	4309701.65	641650.21	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	97	4309713.05	641641.11	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	98	4309720.18	641636.30	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	100	4309724.72	641654.05	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	101	4309733.47	641655.23	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	102	4309740.66	641646.02	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	103	4309749.19	641637.01	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	104	4309746.15	641659.91	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	105	4309736.62	641672.71	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	106	4309744.70	641680.61	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	107	4309743.43	641695.05	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	108	4309737.95	641686.85	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	109	4309737.30	641680.23	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	110	4309721.73	641673.21	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	111	4309721.85	641661.97	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	112	4309717.48	641654.64	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	113	4309713.89	641647.61	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	114	4309699.44	641657.94	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	117	4309682.41	641623.27	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	118	4309681.46	641638.28	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	119	4309674.72	641644.17	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	120	4309683.27	641646.86	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	121	4309691.65	641660.95	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	122	4309699.04	641666.67	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	123	4309707.43	641670.52	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	124	4309716.36	641670.84	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	125	4309707.77	641677.97	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	126	4309695.10	641686.27	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	127	4309707.40	641689.42	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	128	4309706.08	641696.89	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	132	4309726.26	641690.09	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	133	4309724.23	641697.04	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	150	4309556.93	641450.20	unknown	nonordnance	high	unknown	unknown	-99	-99	unknown	
BAT	E1	4309865.25	641598.98	0.23	nonordnance	high	unknown	unknown	336	-99	unknown	0.7
BAT	E2	4309807.14	641579.38	0.51	nonordnance	high	unknown	unknown	338	-99	unknown	0.77
BAT	E5	4309817.10	641578.44	0.64	nonordnance	high	unknown	unknown	289	-99	unknown	0.67
BAT	E8	4309812.12	641578.91	1.07	nonordnance	high	unknown	unknown	299	-99	unknown	0.68
BAT	E10	4309791.73	641586.37	0.27	nonordnance	high	unknown	unknown	314	-99	unknown	0.61
Note 1: Due to angular ambiguity, the azimuth orientation may be equal to theta +/- n times 90 degrees, where n is 0,1,2,3… and theta is the angle listed in the												
azimuth column.												
Note 2: The Comments column contains the estimated length in meters of each ordnance target.												



%TP = (Correct Ordnance Declarations / TOB) x 100

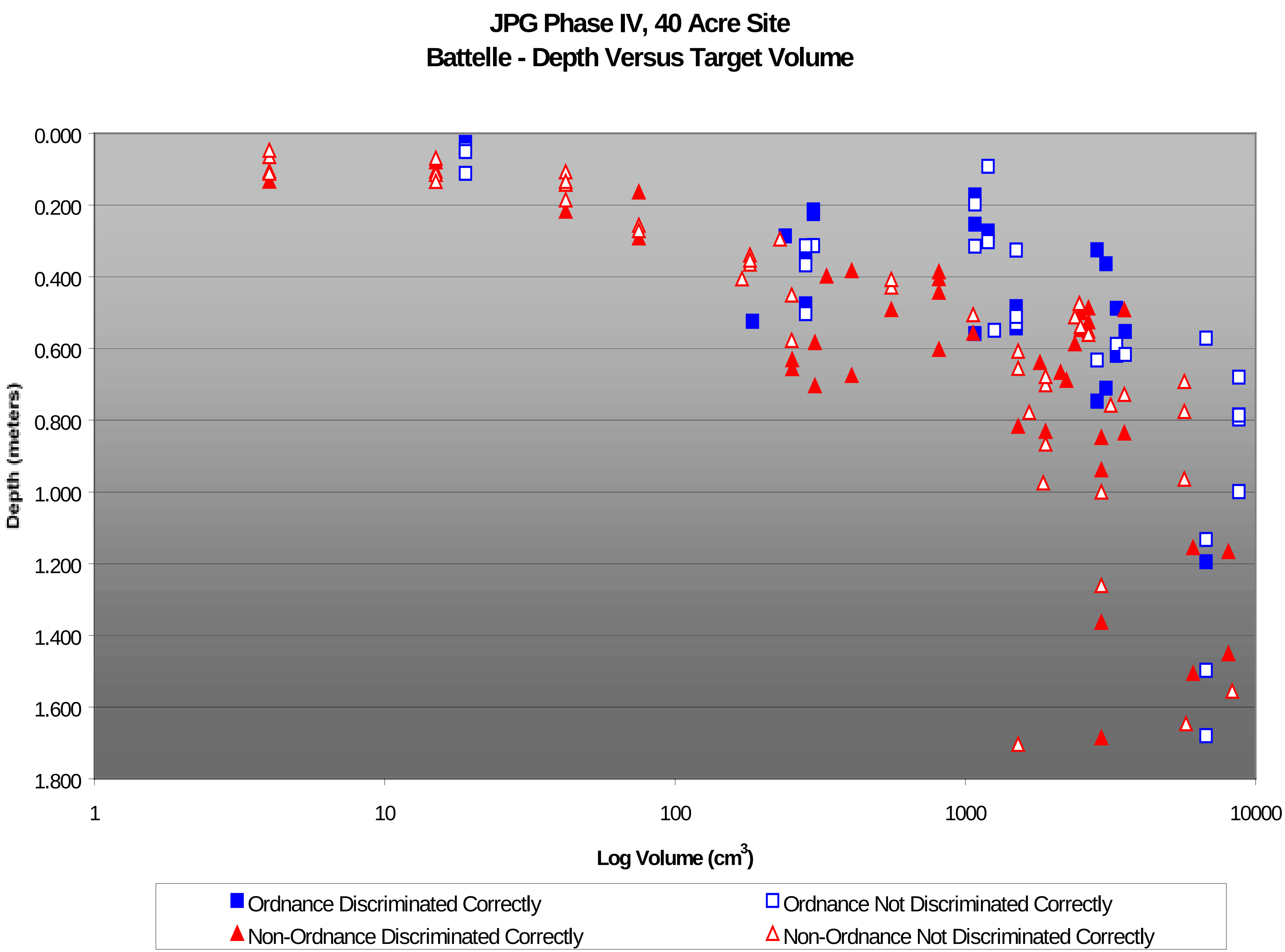
%TN = (Correct Non-Ordnance Declarations / TNOB) x 100

%FP = (Non-Ordnance Declared as Ordnance / TNOB) x 100

%Ou = (Ordnance Declared as Unknown / TOB) x 100

%Nu = (Non-Ordnance Declared as Unknown / TNOB) x 100

%FN = (Ordnance Declared as Non-Ordnance / TOB) x 100



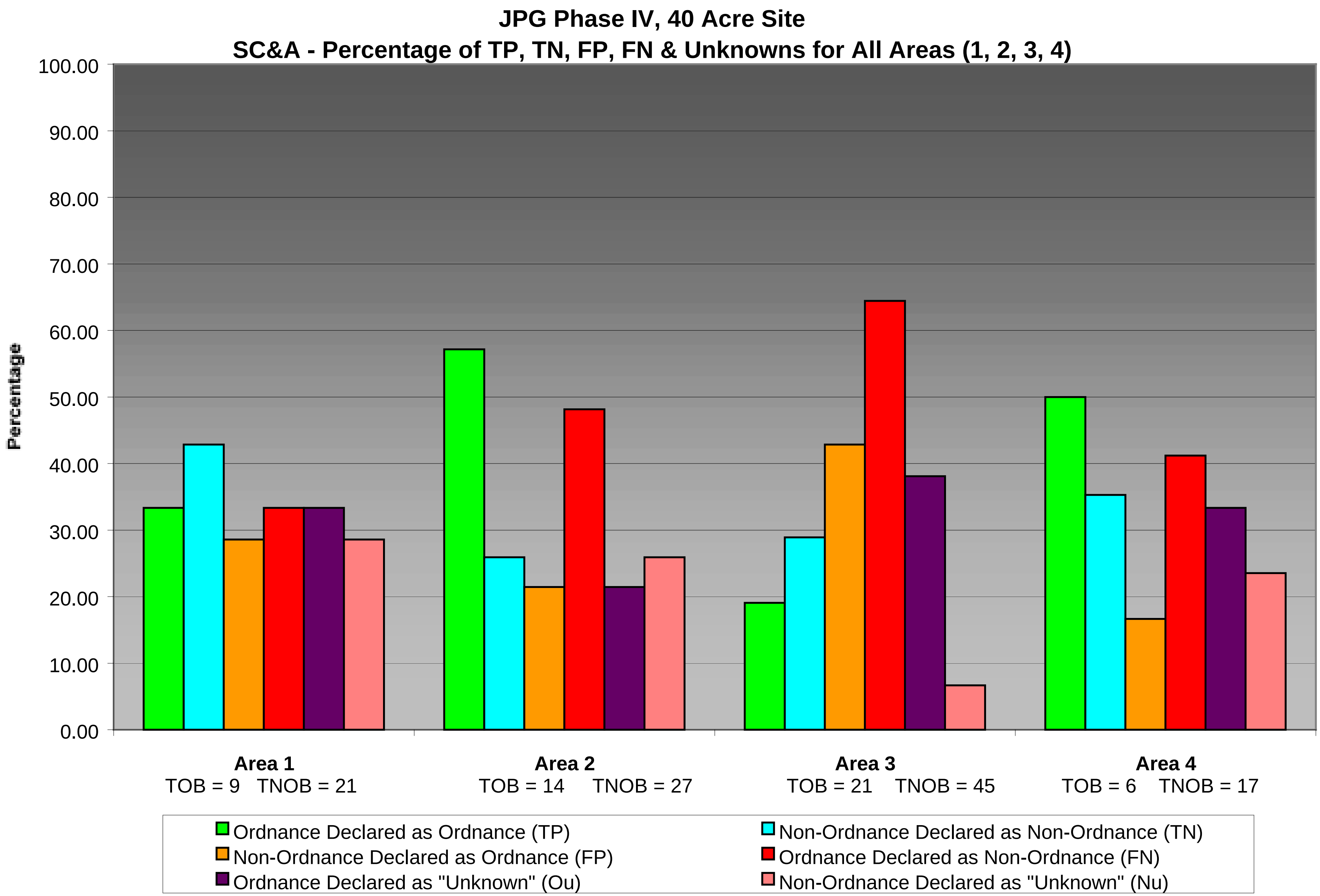
25 Targets missing from the Non-Ordnance Baseline

Sanford, Cohen & Associates

demonstrator	target	rank	northing	easting	depth	type	confidence	weight	size	azimuth	declination	class	comments
SC&A	0090	1	4309731.48	641627.1256	m	ordnance	high	unknown	unknown	-99	unknown	unknown	
SC&A	0008	2	4309689.964	641519.4151	m	ordnance	medium	unknown	unknown	45	unknown	unknown	
SC&A	0052	3	4309493.911	641651.4811	m	ordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0091	4	4309731.88	641636.3398	m	ordnance	high	unknown	unknown	-99	unknown	unknown	
SC&A	0148	5	4309565.402	641459.268	m	ordnance	low	unknown	unknown	45	unknown	unknown	
SC&A	0141	6	4309583.901	641441.6773	s	ordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0152	7	4309557.98	641426.6787	m	ordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0057	8	4309487.487	641674.0428	m	ordnance	medium	unknown	unknown	45	unknown	unknown	
SC&A	0079	9	4309723.153	641592.1086	m	ordnance	medium	unknown	unknown	-99	unknown	unknown	
SC&A	0065	10	4309547.094	641676.5865	m	ordnance	medium	unknown	unknown	45	unknown	unknown	
SC&A	0046	11	4309520.274	641636.6327	m	ordnance	medium	unknown	unknown	-99	unknown	unknown	
SC&A	0063	12	4309526.938	641666.1392	s	ordnance	high	unknown	unknown	135	unknown	unknown	
SC&A	0045	13	4309513.314	641635.2695	m	ordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0076	14	4309745.938	641596.0905	m	ordnance	medium	unknown	unknown	45	unknown	unknown	
SC&A	0147	15	4309564.8	641443.9335	m	ordnance	medium	unknown	unknown	135	unknown	unknown	
SC&A	0108	16	4309737.948	641686.851	m	ordnance	low	unknown	unknown	0	unknown	unknown	
SC&A	0133	17	4309724.23	641697.0443	s	ordnance	medium	unknown	unknown	45	unknown	unknown	
SC&A	0035	18	4309533.289	641646.4195	m	ordnance	high	unknown	unknown	0	unknown	unknown	
SC&A	0031	19	4309543.454	641641.2868	s	ordnance	medium	unknown	unknown	45	unknown	unknown	
SC&A	0021	20	4309647.792	641513.1396	s	ordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0068	21	4309530.699	641686.6266	s	ordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0154	22	4309552.565	641432.4971	d	ordnance	medium	unknown	unknown	315	unknown	unknown	
SC&A	0087	23	4309752.12	641611.4021	m	ordnance	medium	unknown	unknown	315	unknown	unknown	
SC&A	0012	24	4309704.597	641533.3263	m	ordnance	low	unknown	unknown	135	unknown	unknown	
SC&A	0139	25	4309588.369	641456.7064	s	ordnance	low	unknown	unknown	90	unknown	unknown	
SC&A	0051	26	4309491.989	641640.4295	d	ordnance	high	unknown	unknown	-99	unknown	unknown	
SC&A	0019	27	4309660.158	641525.2945	m	ordnance	medium	unknown	unknown	315	unknown	unknown	
SC&A	0070	28	4309521.627	641686.1291	m	ordnance	medium	unknown	unknown	90	unknown	unknown	
SC&A	0143	29	4309575.883	641458.8054	s	ordnance	medium	unknown	unknown	45	unknown	unknown	
SC&A	0056	30	4309478.608	641677.0733	d	ordnance	high	unknown	unknown	0	unknown	unknown	
SC&A	0009	31	4309676.382	641524.9589	s	ordnance	medium	unknown	unknown	90	unknown	unknown	
SC&A	0134	32	4309719.025	641703.2589	m	ordnance	medium	unknown	unknown	315	unknown	unknown	
SC&A	0027	33	4309637.331	641494.3316	m	ordnance	high	unknown	unknown	315	unknown	unknown	
SC&A	0099	34	4309719.96	641645.3574	m	ordnance	high	unknown	unknown	-99	unknown	unknown	
SC&A	0049	35	4309505.22	641641.0964	m	ordnance	low	unknown	unknown	225	unknown	unknown	
SC&A	0120	36	4309683.273	641646.8557	m	ordnance	low	unknown	unknown	315	unknown	unknown	
SC&A	0131	37	4309718.268	641687.1084	s	ordnance	medium	unknown	unknown	-99	unknown	unknown	
SC&A	0136	38	4309732.423	641703.4278	m	ordnance	low	unknown	unknown	0	unknown	unknown	
SC&A	0032	39	4309539.567	641651.1384	m	ordnance	low	unknown	unknown	0	unknown	unknown	
SC&A	0078	40	4309731.319	641596.0086	m	ordnance	medium	unknown	unknown	135	unknown	unknown	
SC&A	0023	41	4309640.757	641533.11	s	ordnance	medium	unknown	unknown	-99	unknown	unknown	
SC&A	0015	42	4309698.16	641541.1325	m	ordnance	medium	unknown	unknown	90	unknown	unknown	
SC&A	0002	43	4309714.72	641491.1256	m	ordnance	medium	unknown	unknown	45	unknown	unknown	
SC&A	0048	44	4309511.734	641648.6154	m	ordnance	low	unknown	unknown	135	unknown	unknown	
SC&A	0110	45	4309721.726	641673.2145	m	ordnance	low	unknown	unknown	45	unknown	unknown	
SC&A	0077	46	4309738.557	641594.2038	m	ordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0102	47	4309740.661	641646.0157	m	ordnance	low	unknown	unknown	0	unknown	unknown	
SC&A	0135	48	4309725.577	641705.748	m	ordnance	low	unknown	unknown	0	unknown	unknown	
SC&A	0151	49	4309559.189	641438.9692	m	ordnance	medium	unknown	unknown	315	unknown	unknown	
SC&A	0140	50	4309588.103	641447.8817	m	ordnance	medium	unknown	unknown	45	unknown	unknown	
SC&A	0104	51	4309746.146	641659.9074	m	nonordnance	medium	unknown	unknown	45	unknown	unknown	
SC&A	0125	52	4309707.773	641677.9689	m	nonordnance	low	unknown	unknown	0	unknown	unknown	
SC&A	0103	53	4309749.191	641637.0112	s	nonordnance	medium	unknown	unknown	-99	unknown	unknown	interference
SC&A	0093	54	4309713.134	641626.8921	d	nonordnance	low	unknown	unknown	-99	unknown	unknown	
SC&A	0095	55	4309696.285	641636.2818	d	nonordnance	high	unknown	unknown	315	unknown	unknown	
SC&A	0098	56	4309720.176	641636.2995	m	nonordnance	low	unknown	unknown	0	unknown	unknown	
SC&A	0018	57	4309662.058	641508.739	m	nonordnance	low	unknown	unknown	-99	unknown	unknown	
SC&A	0067	58	4309537.076	641680.9031	s	nonordnance	low	unknown	unknown	0	unknown	unknown	
SC&A	0003	59	4309723.489	641489.9575	s	nonordnance	low	unknown	unknown	-99	unknown	unknown	
SC&A	0060	60	4309497.795	641670.6678	m	nonordnance	medium	unknown	unknown	45	unknown	unknown	
SC&A	0088	61	4309739.79	641623.5044	s	nonordnance	low	unknown	unknown	-99	unknown	unknown	
SC&A	0145	62	4309571.699	641434.7353	s	nonordnance	low	unknown	unknown	0	unknown	unknown	
SC&A	0062	63	4309517.978	641669.516	s	nonordnance	high	unknown	unknown	-99	unknown	unknown	
SC&A	0064	64	4309538.889	641668.4821	s	nonordnance	low	unknown	unknown	135	unknown	unknown	

SC&A	0081	65	4309715.746	641601.877	s	nonordnance	low	unknown	unknown	-99	unknown	unknown	hole at target
SC&A	0101	66	4309733.474	641655.2261	m	nonordnance	low	unknown	unknown	315	unknown	unknown	
SC&A	0059	67	4309492.008	641680.9647	s	nonordnance	low	unknown	unknown	45	unknown	unknown	
SC&A	0074	68	4309750.911	641571.3801	d	nonordnance	medium	unknown	unknown	45	unknown	unknown	
SC&A	0005	69	4309699.315	641487.2952	s	nonordnance	low	unknown	unknown	-99	unknown	unknown	
SC&A	0066	70	4309543.169	641685.2422	s	nonordnance	high	unknown	unknown	-99	unknown	unknown	
SC&A	0096	71	4309701.645	641650.2054	m	nonordnance	medium	unknown	unknown	45	unknown	unknown	
SC&A	0030	72	4309631.138	641481.1569	m	nonordnance	high	unknown	unknown	45	unknown	unknown	
SC&A	0053	73	4309502.131	641654.4569	m	nonordnance	low	unknown	unknown	45	unknown	unknown	
SC&A	0016	74	4309685.348	641538.4751	d	nonordnance	medium	unknown	unknown	45	unknown	unknown	
SC&A	0029	75	4309639.57	641477.0149	m	nonordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0128	76	4309706.081	641696.8856	s	nonordnance	medium	unknown	unknown	45	unknown	unknown	
SC&A	0109	77	4309737.304	641680.2341	m	nonordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0112	78	4309717.48	641654.636	m	nonordnance	high	unknown	unknown	315	unknown	unknown	
SC&A	0111	79	4309721.851	641661.9743	d	nonordnance	low	unknown	unknown	315	unknown	unknown	
SC&A	0073	80	4309732.612	641580.4389	d	nonordnance	high	unknown	unknown	45	unknown	unknown	
SC&A	0100	81	4309724.723	641654.0519	s	nonordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0084	82	4309730.047	641610.9674	m	nonordnance	medium	unknown	unknown	-99	unknown	unknown	
SC&A	0014	83	4309700.031	641516.8877	m	nonordnance	medium	unknown	unknown	90	unknown	unknown	
SC&A	0010	84	4309671.286	641533.8465	d	nonordnance	medium	unknown	unknown	315	unknown	unknown	
SC&A	0082	85	4309712.379	641610.3568	s	nonordnance	high	unknown	unknown	-99	unknown	unknown	
SC&A	0085	86	4309737.758	641607.0157	s	nonordnance	low	unknown	unknown	315	unknown	unknown	
SC&A	0123	87	4309707.427	641670.5189	m	nonordnance	low	unknown	unknown	45	unknown	unknown	
SC&A	0061	88	4309511.168	641664.395	s	nonordnance	medium	unknown	unknown	-99	unknown	unknown	
SC&A	0105	89	4309736.616	641672.7084	s	nonordnance	medium	unknown	unknown	-99	unknown	unknown	
SC&A	0075	90	4309753.53	641588.1663	m	nonordnance	medium	unknown	unknown	-99	unknown	unknown	
SC&A	0144	91	4309576.944	641442.021	s	nonordnance	high	unknown	unknown	-99	unknown	unknown	
SC&A	0121	92	4309691.65	641660.9546	s	nonordnance	medium	unknown	unknown	-99	unknown	unknown	
SC&A	0038	93	4309524.923	641621.8741	s	nonordnance	high	unknown	unknown	90	unknown	unknown	
SC&A	0071	94	4309511.257	641685.8505	s	nonordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0086	95	4309745.253	641608.3113	s	nonordnance	medium	unknown	unknown	-99	unknown	unknown	
SC&A	0054	96	4309488.642	641658.9909	s	nonordnance	high	unknown	unknown	315	unknown	unknown	
SC&A	0026	97	4309636.739	641511.6791	s	nonordnance	high	unknown	unknown	-99	unknown	unknown	
SC&A	0020	98	4309656.014	641500.356	s	nonordnance	medium	unknown	unknown	-99	unknown	unknown	
SC&A	0089	99	4309739.383	641631.7813	s	nonordnance	low	unknown	unknown	-99	unknown	unknown	
SC&A	0055	100	4309481.433	641663.2956	s	nonordnance	low	unknown	unknown	45	unknown	unknown	
SC&A	0033	101	4309536.121	641637.0525	s	nonordnance	medium	unknown	unknown	-99	unknown	unknown	
SC&A	0083	102	4309721.053	641611.7808	s	nonordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0146	103	4309566.485	641426.0077	s	nonordnance	medium	unknown	unknown	-99	unknown	unknown	
SC&A	0050	104	4309500.508	641633.4921	s	nonordnance	high	unknown	unknown	0	unknown	unknown	
SC&A	0034	105	4309542.756	641627.6585	s	nonordnance	medium	unknown	unknown	-99	unknown	unknown	
SC&A	0069	106	4309529.651	641675.5922	s	nonordnance	high	unknown	unknown	-99	unknown	unknown	
SC&A	0157	107	4309539.57	641422.2841	s	nonordnance	low	unknown	unknown	315	unknown	unknown	
SC&A	0153	108	4309551.55	641418.8173	d	nonordnance	low	unknown	unknown	90	unknown	unknown	
SC&A	0160	109	4309533.937	641457.3376	d	nonordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0150	110	4309556.935	641450.1952	d	nonordnance	high	unknown	unknown	45	unknown	unknown	
SC&A	0149	111	4309557.232	641460.6456	m	nonordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0130	112	4309713.816	641693.2683	m	nonordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0126	113	4309695.101	641686.2686	s	nonordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0122	114	4309699.042	641666.668	s	nonordnance	low	unknown	unknown	-99	unknown	unknown	
SC&A	0118	115	4309681.458	641638.2797	m	nonordnance	medium	unknown	unknown	-99	unknown	unknown	
SC&A	0127	116	4309707.395	641689.4222	s	nonordnance	medium	unknown	unknown	-99	unknown	unknown	
SC&A	0115	117	4309694.869	641643.2166	s	nonordnance	medium	unknown	unknown	-99	unknown	unknown	
SC&A	0119	118	4309674.722	641644.1734	d	nonordnance	high	unknown	unknown	45	unknown	unknown	
SC&A	0114	119	4309699.443	641657.9399	s	nonordnance	medium	unknown	unknown	-99	unknown	unknown	
SC&A	0013	120	4309684.844	641503.1903	m	nonordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0107	121	4309743.431	641695.0465	d	nonordnance	high	unknown	unknown	315	unknown	unknown	
SC&A	0106	122	4309744.704	641680.6079	m	nonordnance	medium	unknown	unknown	90	unknown	unknown	
SC&A	0116	123	4309688.47	641631.8135	d	nonordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0006	124	4309707.478	641478.9258	m	nonordnance	low	unknown	unknown	-99	unknown	unknown	
SC&A	0001	unknown	4309722.703	641501.6964	m	unknown	unknown	unknown	unknown	0	unknown	unknown	
SC&A	0004	unknown	4309712.451	641508.1419	m	unknown	unknown	unknown	unknown	0	unknown	unknown	
SC&A	0007	unknown	4309695.306	641497.248	m	unknown	unknown	unknown	unknown	-99	unknown	unknown	
SC&A	0011	unknown	4309711.925	641524.5496	m	unknown	unknown	unknown	unknown	-99	unknown	unknown	
SC&A	0017	unknown	4309666.496	641517.3798	s	unknown	unknown	unknown	unknown	-99	unknown	unknown	
SC&A	0022	unknown	4309648.858	641528.6493	m	unknown	unknown	unknown	unknown	45	unknown	unknown	
SC&A	0024	unknown	4309633.699	641524.6555	unknown	unknown	unknown	unknown	unknown	-99	unknown	unknown	interference
SC&A	0025	unknown	4309647.941	641494.9067	s	unknown	unknown	unknown	unknown	0	unknown	unknown	

SC&A	0028	unknown	4309648.346	641480.0782	m	unknown	unknown	unknown	unknown	45	unknown	unknown	
SC&A	0036	unknown	4309531.066	641627.8857	m	unknown	unknown	unknown	unknown	0	unknown	unknown	
SC&A	0037	unknown	4309527.775	641639.3732	s	unknown	unknown	unknown	unknown	-99	unknown	unknown	
SC&A	0039	unknown	4309517.603	641625.2732	unknown	unknown	unknown	unknown	unknown	-99	unknown	unknown	interference
SC&A	0040	unknown	4309531.608	641607.3828	unknown	unknown	unknown	unknown	unknown	-99	unknown	unknown	interference
SC&A	0041	unknown	4309525.663	641610.2988	unknown	unknown	unknown	unknown	unknown	-99	unknown	unknown	interference
SC&A	0042	unknown	4309518.166	641604.8853	unknown	unknown	unknown	unknown	unknown	-99	unknown	unknown	interference
SC&A	0043	unknown	4309512.933	641612.7706	unknown	unknown	unknown	unknown	unknown	-99	unknown	unknown	interference
SC&A	0044	unknown	4309506.92	641625.3579	unknown	unknown	unknown	unknown	unknown	-99	unknown	unknown	interference
SC&A	0047	unknown	4309518.956	641646.0144	s	unknown	unknown	unknown	unknown	0	unknown	unknown	
SC&A	0058	unknown	4309485.956	641684.1457	s	unknown	unknown	unknown	unknown	45	unknown	unknown	
SC&A	0072	unknown	4309741.848	641580.8004	unknown	unknown	unknown	unknown	unknown	-99	unknown	unknown	interference
SC&A	0080	unknown	4309724.92	641583.6774	m	unknown	unknown	unknown	unknown	-99	unknown	unknown	
SC&A	0092	unknown	4309721.188	641626.856	m	unknown	unknown	unknown	unknown	-99	unknown	unknown	
SC&A	0094	unknown	4309710.066	641634.0774	d	unknown	unknown	unknown	unknown	270	unknown	unknown	
SC&A	0097	unknown	4309713.054	641641.107	m	unknown	unknown	unknown	unknown	-99	unknown	unknown	
SC&A	0113	unknown	4309713.893	641647.605	m	unknown	unknown	unknown	unknown	-99	unknown	unknown	
SC&A	0117	unknown	4309682.41	641623.2747	m	unknown	unknown	unknown	unknown	-99	unknown	unknown	
SC&A	0124	unknown	4309716.362	641670.8394	m	unknown	unknown	unknown	unknown	-99	unknown	unknown	interference
SC&A	0129	unknown	4309711.326	641704.3392	s	unknown	unknown	unknown	unknown	-99	unknown	unknown	
SC&A	0132	unknown	4309726.261	641690.0878	m	unknown	unknown	unknown	unknown	-99	unknown	unknown	
SC&A	0137	unknown	4309738.07	641699.6002	m	unknown	unknown	unknown	unknown	-99	unknown	unknown	
SC&A	0138	unknown	4309591.082	641465.635	unknown	unknown	unknown	unknown	unknown	-99	unknown	unknown	interference
SC&A	0142	unknown	4309581.781	641450.0555	m	unknown	unknown	unknown	unknown	-99	unknown	unknown	
SC&A	0155	unknown	4309548.951	641445.8415	s	unknown	unknown	unknown	unknown	-99	unknown	unknown	
SC&A	0156	unknown	4309543.94	641436.5504	s	unknown	unknown	unknown	unknown	-99	unknown	unknown	
SC&A	0158	unknown	4309535.239	641432.6788	s	unknown	unknown	unknown	unknown	-99	unknown	unknown	
SC&A	0159	unknown	4309540.58	641449.2209	s	unknown	unknown	unknown	unknown	-99	unknown	unknown	
	WES AREA												
SC&A	0161	not ranked	4309865.25	641598.98	s	ordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0162	not ranked	4309807.14	641579.38	s	ordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0163	not ranked	4309820.64	641615.77	s	nonordnance	high	unknown	unknown	-99	unknown	unknown	
SC&A	0164	not ranked	4309799.18	641580.14	s	ordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0165	not ranked	4309817.1	641578.44	s	ordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0166	not ranked	4309807.66	641584.86	s	nonordnance	high	unknown	unknown	0	unknown	unknown	
SC&A	0167	not ranked	4309880.06	641622.68	unknown	unknown	unknown	unknown	unknown	-99	unknown	unknown	interference
SC&A	0168	not ranked	4309812.12	641578.91	s	ordnance	medium	unknown	unknown	0	unknown	unknown	
SC&A	0169	not ranked	4309812.64	641584.38	s	nonordnance	high	unknown	unknown	-99	unknown	unknown	
SC&A	0170	not ranked	4309791.73	641586.37	s	ordnance	medium	unknown	unknown	0	unknown	unknown	



%TP = (Correct Ordnance Declarations / TOB) x 100

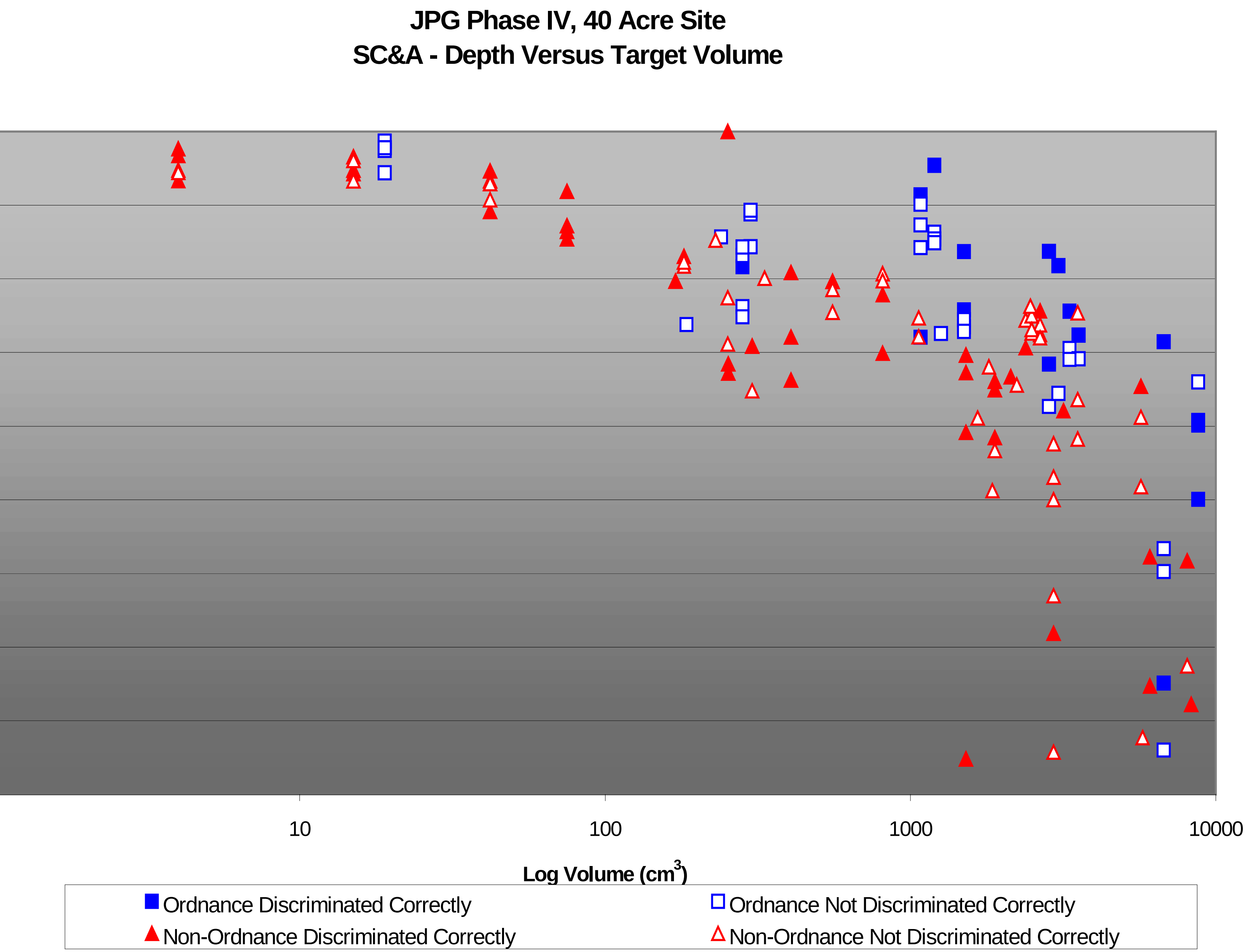
%TN = (Correct Non-Ordnance Declarations / TNOB) x 100

%FP = (Non-Ordnance Declared as Ordnance / TNOB) x 100

%Ou = (Ordnance Declared as Unknown / TOB) x 100

%Nu = (Non-Ordnance Declared as Unknown / TNOB) x 100

%FN = (Ordnance Declared as Non-Ordnance / TOB) x 100



gets missing from the Non-Ordnance Baseline

ADI/Alpha Geoscience Pty. Limited

demonstrator	target	northing	easting	depth	type	confidence	weight	size	azimuth	declination	class	comments	Value
021	90	4309731.4799	641627.1256	0.76	Ordnance	High	Moderate	Medium	210	16	Projectile	Medium diameter projectile	9.75
021	102	4309740.6605	641646.0157	0.38	Ordnance	High	Light	Small	60	15	Projectile		9.5
021	103	4309749.1911	641637.0112	0.81	Ordnance	High	Moderate	Medium	330	15	Projectile		9.5
021	30	4309631.1377	641481.1569	0.78	Ordnance	High	Moderate	Small	0	15	Projectile	Length 55~60 cm	9.5
021	56	4309478.6079	641677.0733	1.07	Ordnance	High	Moderate	Medium	90	0	Projectile	Large shell - 155 mm diam.	9.5
021	141	4309583.9011	641441.6773	0.63	Ordnance	High	Light	Small	90	0	Mortar	Bomb shape, poss mortar ?	9
021	2	4309714.7198	641491.1256	0.44	Ordnance	High	Light	Small	90	20	Mortar		9
021	23	4309640.7573	641533.1100	0.54	Ordnance	High	Light	Small	0	15	Projectile	Approx 46cm long, sharp point	9
021	99	4309719.9596	641645.3574	0.36	Ordnance	High	Light	Small	130	20	Mortar		9
021	134	4309719.0252	641703.2589	0.96	Ordnance	High	Light	Medium	270	20	Mortar	Alum. nose & fins	8.75
021	14	4309700.0305	641516.8877	0.85	Ordnance	Moderate	Moderate	Small	190	15	Mortar		8.5
021	15	4309698.1601	641541.1325	0.69	Ordnance	Moderate	Light	Medium	90	15	Projectile	Coax cable visible on surface	8.5
021	28	4309648.3457	641480.0782	0.26	Ordnance	Moderate	Light	Medium	90	0	Projectile	Flat lying, cylindical	8.5
021	39	4309517.6033	641625.2732	0.2	Ordnance	Moderate	Light	Medium	0	15	Projectile		8.5
021	46	4309520.2743	641636.6327	0.25	Ordnance	Moderate	Light	Small	0	10	Projectile		8.5
021	62	4309517.9778	641669.5160	0.12	Ordnance	Moderate	Light	Small	0	15	Projectile		8.5
021	72	4309741.8481	641580.8004	0.11	Ordnance	Moderate	Light	Small	340	5	Projectile	Small, round, shallow	8.5
021	98	4309720.1761	641636.2995	0.6	Ordnance	Moderate	Light	Medium	90	15	Mortar	Mortar w. fins projectile	8.5
021	113	4309713.8929	641647.6050	0.15	Ordnance	Moderate	Light	Small	0	10	Projectile	Small pipe with disc on top?	8
021	138	4309591.0823	641465.6350	0.64	Ordnance	Moderate	Light	Small	320	5	Mortar	Possible Mortar ?	8
021	154	4309552.5653	641432.4971	0.51	Ordnance	Moderate	Light	Small	325	0	Mortar	Mortar w. fins?	8
021	159	4309540.5800	641449.2209	0.24	Ordnance	Moderate	Light	Small	90	0	Mortar	Mortar w. fins	8
021	8	4309689.9635	641519.4151	0.77	Ordnance	Moderate	Moderate	Small	45	-99	Projectile	Medium projectile	8
021	88	4309739.7898	641623.5044	0.3	Ordnance	Moderate	Light	Small	180	5	Projectile		8
021	131	4309718.2679	641687.1084	0.59	Ordnance	Moderate	Light	Small	45	10	Projectile		7.5
021	70	4309521.6268	641686.1291	0.5	Ordnance	Moderate	Light	Small	8	0	Projectile	76 mm. projectile	7.5
021	74	4309750.9106	641571.3801	0.17	Ordnance	Moderate	Light	Small	0	5	Projectile	Shallow, oval	7.5
021	75	4309753.5295	641588.1663	0.2	Ordnance	Moderate	Light	Small	0	10	Projectile	Small diameter	7.5
021	81	4309715.7457	641601.8770	0.38	Ordnance	Moderate	Light	Small	180	5	Projectile	Small	7.5

												projectile	
021	150	4309556.9346	641450.1952	0.83	Ordnance	Moderate	Light	Medium	90	5	Projectile	2 straight linear sides	7.25
021	108	4309737.9479	641686.8510	0.83	Ordnance	Moderate	Moderate	Small	0	10	Projectile		7
021	139	4309588.3687	641456.7064	0.97	Ordnance	Moderate	Moderate	Small	90	0	Mortar	Mortar ?	7
021	156	4309543.9401	641436.5504	0.35	Ordnance	Moderate	Light	Small	90	0	Mortar	Target 0.5 m. away from flag	7
021	17	4309666.4957	641517.3798	0.3	Ordnance	Moderate	Light	Small	0	25	Mortar	76 mm Mortar	7
021	19	4309660.1581	641525.2945	0.54	Ordnance	Moderate	Light	Medium	120	0	Projectile	Round top	7
021	37	4309527.7748	641639.3732	0.22	Ordnance	Moderate	Light	Small	135	10	Projectile		7
021	61	4309511.1684	641664.3950	0.33	Ordnance	Moderate	Light	Small	135	10	Projectile		7
021	63	4309526.9378	641666.1392	0.15	Ordnance	Low	Light	Small	155	15	Mortar	Mortar or 2 incl. Pipes	7
021	105	4309736.6163	641672.7084	0.15	Ordnance	Low	Light	Small	210	10	Projectile	20mm pipe 125mm long w. disk	6.75
021	57	4309487.4870	641674.0428	0.66	Ordnance	Low	Light	Small	210	5	Projectile	Small compact target	6.5
021	116	4309688.4696	641631.8135	0.3	Ordnance	Low	Light	Small	270	5	Projectile	Small cyl. & small 0.5 m from flag	6
021	119	4309674.7221	641644.1734	0.52	Ordnance	Low	Light	Small	330	10	Mortar	Mortar with long alum. Tail	6
021	157	4309539.5701	641422.2841	0.24	Ordnance	Low	Light	Small	20	0	Mortar	Small mortar	6
021	18	4309662.0578	641508.7390	0.35	Ordnance	Low	Light	Small	0	-99	Projectile	Round, short, small	6
021	35	4309533.2889	641646.4195	0.63	Ordnance	Low	Light	Small	0	5	Projectile	60 mm. projectile	6
021	10	4309671.2855	641533.8465	1.6	Non-Ordnance	Low	Heavy	Large	-99	-99			5
021	112	4309717.4803	641654.6360	1.3	Unknown	Unknown	Heavy	Medium	-99	-99			5
021	114	4309699.4430	641657.9399	0.4	Non-Ordnance	Unknown	Light	Small	-99	-99		V. rough ground surface	5
021	38	4309524.9229	641621.8741	0.2	Non-Ordnance	Low	Light	Small	-99	-99		Small disc or pipe	5
021	54	4309488.6424	641658.9909	1.6	Non-Ordnance	Unknown	Light	Medium	-99	-99			5
021	65	4309547.0936	641676.5865	0.44	Non-Ordnance	Moderate	Moderate	Medium	90	0		Rectangular steel plate	5
021	73	4309732.6124	641580.4389	0.97	Non-Ordnance	Low	Moderate	Small	35	0		Metal block 24 x 14 cm ?	5
021	87	4309752.1200	641611.4021	0.4	Non-Ordnance	Unknown	Light	Small	-99	-99			5
021	9	4309676.3815	641524.9589	0.8	Non-Ordnance	Low	Moderate	Small	0	10		Pipe with end plates	5
021	96	4309701.6451	641650.2054	0.7	Non-Ordnance	Low	Moderate	Medium	0	0		No clear target visible	5
021	97	4309713.0544	641641.1070	0.66	Non-Ordnance	Low	Light	Medium	45	-99		2 unclear targets	5

021	31	4309543.4536	641641.2868	0.29	Non-Ordnance	Moderate	Light	Small	0	0		Flat steel plate	4.5
021	32	4309539.5670	641651.1384	0.53	Non-Ordnance	Moderate	Light	Small	90	0		Short H section w. disc	4.5
021	48	4309511.7342	641648.6154	0.47	Non-Ordnance	Low	Light	Small	135	0		Rectangular block of steel	4.5
021	69	4309529.6511	641675.5922	0.62	Non-Ordnance	Low	Light	Small	-99	0		Steel ring or small plate	4.5
021	80	4309724.9196	641583.6774	0.28	Non-Ordnance	Low	Light	Small	225	10		Small pipe w. circular disk	4.5
021	93	4309713.1336	641626.8921	1.62	Non-Ordnance	Low	Moderate	Medium	90	0		Rect. steel block	4.5
021	41	4309525.6634	641610.2988	0.65	Non-Ordnance	Low	Light	Small	135	7		Short pipe with attachment	4.25
021	115	4309694.8690	641643.2166	0.63	Non-Ordnance	Moderate	Light	Medium	0	5		U or H channel section?	4
021	120	4309683.2732	641646.8557	0.45	Non-Ordnance	Moderate	Light	Small	0	10		Pipe with attachment	4
021	124	4309716.3620	641670.8394	0.36	Non-Ordnance	Moderate	Light	Small	-99	0		Small disk	4
021	13	4309684.8441	641503.1903	0.3	Non-Ordnance	Moderate	Light	Small	-99	-99		Round disk ?	4
021	132	4309726.2612	641690.0878	0.66	Non-Ordnance	Moderate	Light	Medium	0	10		Prob. block/box section	4
021	135	4309725.5767	641705.7480	0.9	Non-Ordnance	Moderate	Light	Medium	180	10		Long pipe w. section attached	4
021	145	4309571.6988	641434.7353	0.55	Non-Ordnance	Moderate	Light	Small	15	0		Pipe w. end plates & s. pipe handle	4
021	155	4309548.9508	641445.8415	0.2	Non-Ordnance	Moderate	Light	Small	0	0		Small target, round disc ?	4
021	51	4309491.9892	641640.4295	1.62	Non-Ordnance	Moderate	Light	Small	330	-99		Flat plate	4
021	6	4309707.4780	641478.9258	0.3	Non-Ordnance	Moderate	Light	Small	-99	-99		2 targets 0.3 & 0.52 m depth	4
021	76	4309745.9382	641596.0905	0.51	Non-Ordnance	Moderate	Light	Medium	0	0		Pipe, w. sect. welded on top	4
021	77	4309738.5574	641594.2038	0.68	Non-Ordnance	Moderate	Light	Medium	355	0		Steel plate w. center hole	4
021	92	4309721.1882	641626.8560	1.5	Non-Ordnance	Moderate	Moderate	Medium	90	0		Steel block w.center hole	4
021	95	4309696.2846	641636.2818	0.7	Non-Ordnance	Moderate	Moderate	Medium	330	0		U or H Channel section?	4
021	109	4309737.3039	641680.2341	0.25	Non-	Moderate	Light	Small	0	0		Small	3.5

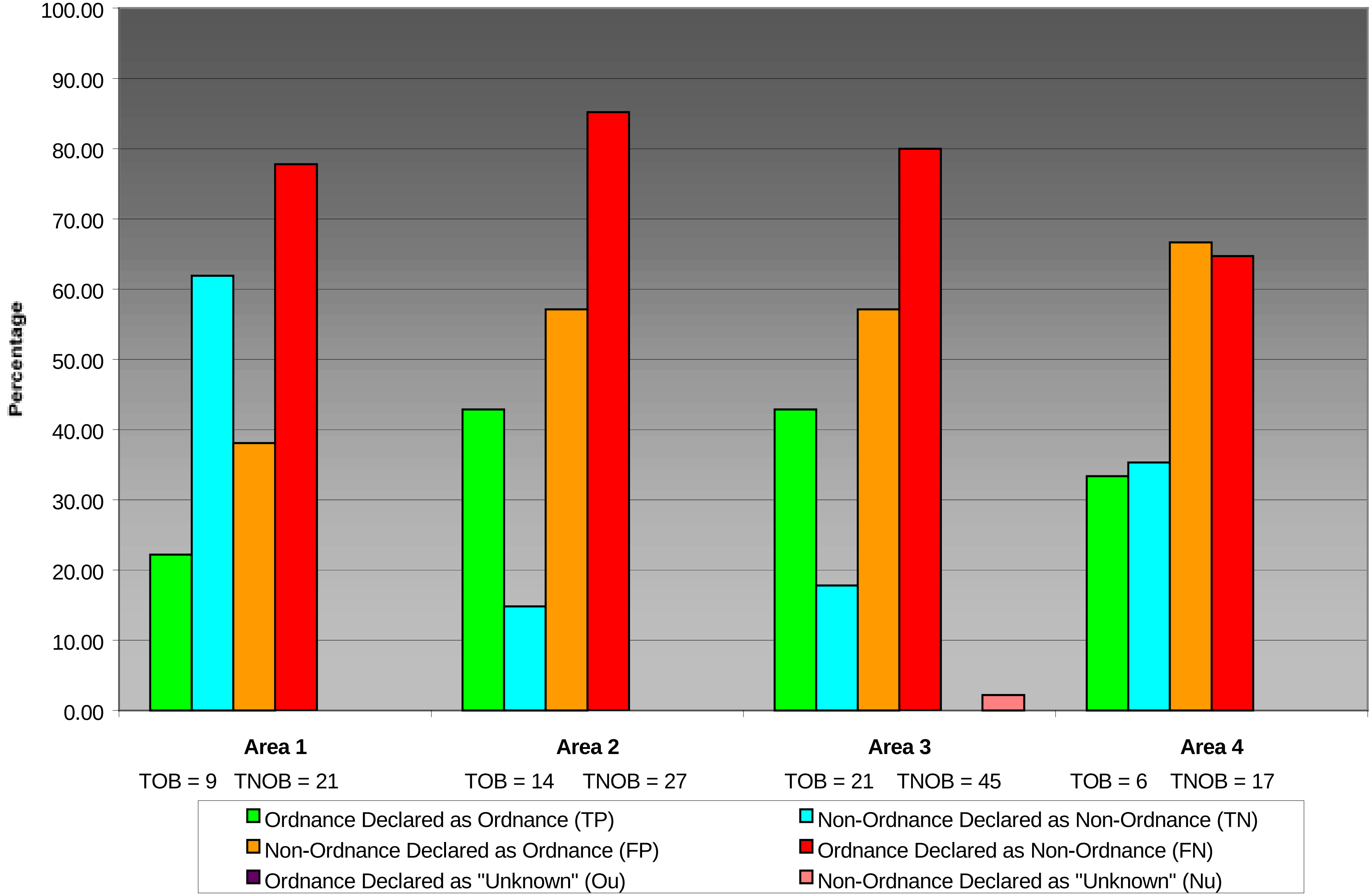
					Ordnance							pipe or flat plate	
021	118	4309681.4582	641638.2797	0.54	Non-Ordnance	Moderate	Light	Small	90	0			3.5
021	53	4309502.1307	641654.4569	0.32	Non-Ordnance	Moderate	Moderate	Medium	240	15		Small pipe w. disks on top	3.5
021	79	4309723.1531	641592.1086	0.34	Non-Ordnance	Moderate	Light	Small	90	0		Backfill distorted target	3.5
021	101	4309733.4743	641655.2261	0.45	Non-Ordnance	Moderate	Light	Medium	90	0		2 crossed steel plates	3
021	107	4309743.4314	641695.0465	0.3	Non-Ordnance	Moderate	Light	Small	270	10		Small, round, shallow	3
021	121	4309691.6496	641660.9546	0.51	Non-Ordnance	Moderate	Light	Medium	270	5		Pipe with plate on top	3
021	122	4309699.0424	641666.6680	0.58	Non-Ordnance	Moderate	Light	Medium	270	15		2 pipes with plate	3
021	130	4309713.8164	641693.2683	0.52	Non-Ordnance	Moderate	Light	Small	0	0		H channel or welded block	3
021	136	4309732.4228	641703.4278	0.96	Non-Ordnance	Moderate	Light	Medium	90	10		Block with flat top?	3
021	140	4309588.1029	641447.8817	1	Non-Ordnance	Moderate	Moderate	Small	75	0		Box section with end plates	3
021	142	4309581.7806	641450.0555	0.63	Non-Ordnance	Moderate	Light	Small	90	0		Box of steel plates	3
021	144	4309576.9436	641442.0210	0.34	Non-Ordnance	Moderate	Light	Small	260	10		Flat steel plate	3
021	146	4309566.4851	641426.0077	0.35	Non-Ordnance	Moderate	Light	Medium	270	-99		Complex target 4 steel plates	3
021	148	4309565.4019	641459.2680	0.45	Non-Ordnance	Moderate	Light	Small	80	20		Steel plate, or flat box	3
021	149	4309557.2323	641460.6456	0.67	Non-Ordnance	Moderate	Moderate	Small	90	0		3 pipes with end plates?	3
021	151	4309559.1890	641438.9692	0.68	Non-Ordnance	Moderate	Light	Small	0	5		Rectangular block of metal	3
021	152	4309557.9795	641426.6787	0.58	Non-Ordnance	Moderate	Light	Medium	90	10		Metal box shape	3
021	158	4309535.2390	641432.6788	0.2	Non-Ordnance	Low	Light	Small	-99	0		Metal ring or disc	3
021	160	4309533.9374	641457.3376	0.81	Non-Ordnance	Moderate	Light	Small	180	5		Rectangular blocks	3
021	20	4309656.0144	641500.3560	0.41	Non-Ordnance	Moderate	Light	Medium	-99	-99		2 pipes, off set in depth	3
021	21	4309647.7922	641513.1396	0.58	Non-Ordnance	Moderate	Light	Medium	180	10		Pipe w. attachments	3
021	29	4309639.5701	641477.0149	0.57	Non-Ordnance	Moderate	Moderate	Small	180	5		2 x 3" pipes	3
021	3	4309723.4889	641489.9575	0.3	Non-Ordnance	Moderate	Light	Small	-99	-99		Med/large pipe w. attach?	3

021	33	4309536.1208	641637.0525	0.16	Non-Ordnance	Moderate	Light	Small	180	3		Small pipe?	3
021	34	4309542.7559	641627.6585	0.15	Non-Ordnance	Moderate	Light	Small	-99	0		Small 32mm. Circular Disc	3
021	40	4309531.6078	641607.3828	0.17	Non-Ordnance	Moderate	Light	Medium	0	25		Steeply dipping	3
021	42	4309518.1664	641604.8853	0.36	Non-Ordnance	Moderate	Light	Medium	90	0		H channel w. flat side up	3
021	5	4309699.3145	641487.2952	0.25	Non-Ordnance	Moderate	Light	Small	-99	-99		Round, small	3
021	52	4309493.9107	641651.4811	0.36	Non-Ordnance	Moderate	Light	Medium	270	10		Pipe w. end plates	3
021	55	4309481.4325	641663.2956	0.62	Non-Ordnance	Moderate	Light	Medium	140	0		H channel w. flat side up	3
021	66	4309543.1691	641685.2422	0.61	Non-Ordnance	Moderate	Light	Medium	180	3		Rectangular steel plate	3
021	68	4309530.6987	641686.6266	0.3	Non-Ordnance	Moderate	Light	Small	0	0		Steel ring or small plate	3
021	7	4309695.3058	641497.2480	0.37	Non-Ordnance	Moderate	Light	Medium	-99	0		Steel plate, lying flat	3
021	71	4309511.2566	641685.8505	0.4	Non-Ordnance	Moderate	Light	Small	0	0		Steel ring or small plate	3
021	78	4309731.3193	641596.0086	0.9	Non-Ordnance	Moderate	Light	Small	10	0		Steel plate w. center hole	3
021	82	4309712.3792	641610.3568	0.41	Non-Ordnance	Moderate	Light	Small	128	0		Steel plate	3
021	94	4309710.0658	641634.0774	0.9	Non-Ordnance	Unknown	Moderate	Small	-99	-99		2x long pipe w. end plates	3
021	100	4309724.7227	641654.0519	0.6	Non-Ordnance	High	Light	Medium	60	0		Thin steel plate	2.5
021	106	4309744.7036	641680.6079	1.1	Non-Ordnance	High	Light	Medium	0	10		U channel, with flat top up	2.5
021	111	4309721.8511	641661.9743	0.7	Non-Ordnance	High	Light	Small	90	0		Block of steel plates ?	2.5
021	117	4309682.4102	641623.2747	0.55	Non-Ordnance	High	Light	Medium	60	0		H section, or plate/pipe	2.5
021	123	4309707.4266	641670.5189	0.38	Non-Ordnance	High	Light	Medium	190	15		2 pipes w. plate on top?	2.5
021	125	4309707.7725	641677.9689	0.41	Non-Ordnance	High	Light	Small	90	0		H section	2.5
021	83	4309721.0529	641611.7808	0.41	Non-Ordnance	High	Light	Medium	45	0		Steel plate with center hole	2.5
021	85	4309737.7579	641607.0157	0.4	Non-Ordnance	High	Light	Medium	120	15		Plate/pipe w. box/H section	2.5
021	129	4309711.3264	641704.3392	0.4	Non-Ordnance	High	Light	Medium	80	0		Flat top. Plate/block	2.25
021	91	4309731.8802	641636.3398	0.56	Non-Ordnance	High	Light	Heavy	90	0		2 rectangul	2.25

												ar steel plates	
021	110	4309721.7257	641673.2145	0.82	Non-Ordnance	High	Moderate	Small	0	0		Complex target. Multi-angle	2
021	12	4309704.5973	641533.3263	0.33	Non-Ordnance	High	Light	Medium	-99	-99		U or H Section above pipe	2
021	128	4309706.0809	641696.8856	0.54	Non-Ordnance	High	Light	Medium	135	5		5" Pipe w. section attached	2
021	133	4309724.2303	641697.0443	0.6	Non-Ordnance	High	Light	Medium	90	0		Steel plate/s, flat lying	2
021	143	4309575.8831	641458.8054	0.72	Non-Ordnance	High	Moderate	Small	80	-99			2
021	147	4309564.7999	641443.9335	0.46	Non-Ordnance	High	Light	Medium	9	0		Steel plate	2
021	153	4309551.5495	641418.8173	0.41	Non-Ordnance	High	Moderate	Medium	90	10		Pipe w. section attached	2
021	16	4309685.3480	641538.4751	0.6	Non-Ordnance	High	Moderate	Medium	20	-99		2 pipes w. plates both ends	2
021	24	4309633.6994	641524.6555	0.83	Non-Ordnance	High	Light	Medium	135	5		4~ 5" pipe w. H sect. att.?	2
021	27	4309637.3312	641494.3316	0.42	Non-Ordnance	High	Light	Medium	270	5		Large round pipe, w. attach	2
021	4	4309712.4513	641508.1419	0.36	Non-Ordnance	High	Light	Medium	15	0		Pipe 35 cm w. end plates	2
021	44	4309506.9198	641625.3579	0.5	Non-Ordnance	High	Light	Small	220	3		2 pipes with 2 flat plates	2
021	50	4309500.5075	641633.4921	0.59	Non-Ordnance	High	Light	Medium	180	15		Large U channel ?	2
021	58	4309485.9556	641684.1457	0.96	Non-Ordnance	High	Light	Medium	90	20		Box / channel section	2
021	60	4309497.7949	641670.6678	0.69	Non-Ordnance	High	Light	Medium	-99	0		Large pipe w. channel sect.	2
021	64	4309538.8893	641668.4821	0.32	Non-Ordnance	High	Light	Medium	0	0		Rectangular block of steel	2
021	84	4309730.0474	641610.9674	0.61	Non-Ordnance	High	Light	Medium	180	0		Box made from steel plates	2
021	104	4309746.1455	641659.9074	0.5	Non-Ordnance	High	Light	Medium	270	30		Complex multiple steel plates	1.5
021	11	4309711.9248	641524.5496	0.76	Non-Ordnance	High	Light	Medium	270	15		5" steel pipe w. U channel	1.5
021	137	4309738.0695	641699.6002	0.69	Non-Ordnance	High	Light	Small	45	0		2 pipes, with circular ring	1.5
021	25	4309647.9414	641494.9067	0.82	Non-Ordnance	High	Light	Medium	260	12		Pipe w. H or box section	1.5

												att.	
021	26	4309636.7391	641511.6791	0.31	Non-Ordnance	High	Light	Medium	-99	0		Pipe w. end plates & handle	1.5
021	45	4309513.3141	641635.2695	0.44	Non-Ordnance	High	Moderate	Small	210	5		Rectangular block of steel	1.5
021	47	4309518.9561	641646.0144	0.44	Non-Ordnance	High	Light	Medium	0	10		Long box section or pipe	1.5
021	86	4309745.2530	641608.3113	0.35	Non-Ordnance	High	Light	Medium	80	0		Steel plate box w. center hole	1.5
021	1	4309722.7032	641501.6964	0.48	Non-Ordnance	High	Light	Small	45	0		Rectangular block of steel	1.25
021	126	4309695.1010	641686.2686	0.48	Non-Ordnance	High	Moderate	Medium	45	0		5 rect. steel plates in block	1.25
021	127	4309707.3951	641689.4222	0.63	Non-Ordnance	High	Light	Medium	45	0		Block of steel plates, welded	1.25
021	43	4309512.9333	641612.7706	0.44	Non-Ordnance	High	Light	Small	105	0		Rectangular steel plate	1.25
021	59	4309492.0082	641680.9647	0.93	Non-Ordnance	High	Moderate	Medium	57	0		Rectanglar block of metal	1.25
021	89	4309739.3830	641631.7813	0.32	Non-Ordnance	High	Light	Medium	-99	-99		4 plates weld. at 90/45 deg.	1.25
021	36	4309531.0660	641627.8857	0.65	Non-Ordnance	High	Light	Small	180	15		Box section w. end plates	1.1
021	22	4309648.8579	641528.6493	0.83	Non-Ordnance	High	Light	Medium	135	5		4"~5"pipe w. H channel beam?	1
021	49	4309505.2202	641641.0964	0.45	Non-Ordnance	High	Moderate	Medium	12	-99		Target 4 plates perpend.	1
021	67	4309537.0763	641680.9031	0.27	Non-Ordnance	High	Light	Medium	279	9		H beam section	1

JPG Phase IV, 40 Acre Site
ADI - Percentage of TP, TN, FP, FN & Unknowns for All Areas (1, 2, 3, 4)



%TP = (Correct Ordnance Declarations / TOB) x 100

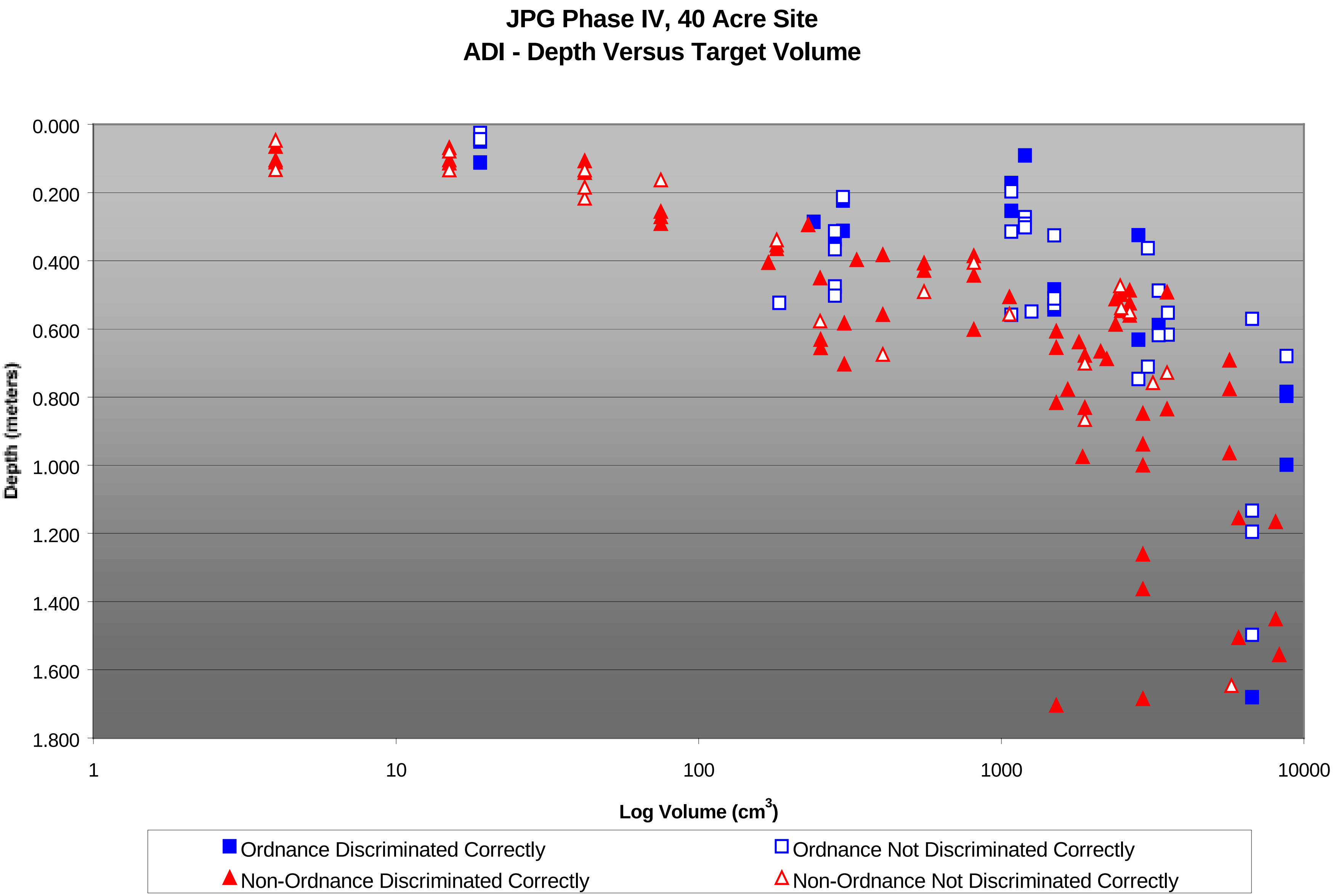
%TN = (Correct Non-Ordnance Declarations / TNOB) x 100

%FP = (Non-Ordnance Declared as Ordnance / TNOB) x 100

%Ou = (Ordnance Declared as Unknown / TOB) x 100

%Nu = (Non-Ordnance Declared as Unknown / TNOB) x 100

%FN = (Ordnance Declared as Non-Ordnance / TOB) x 100



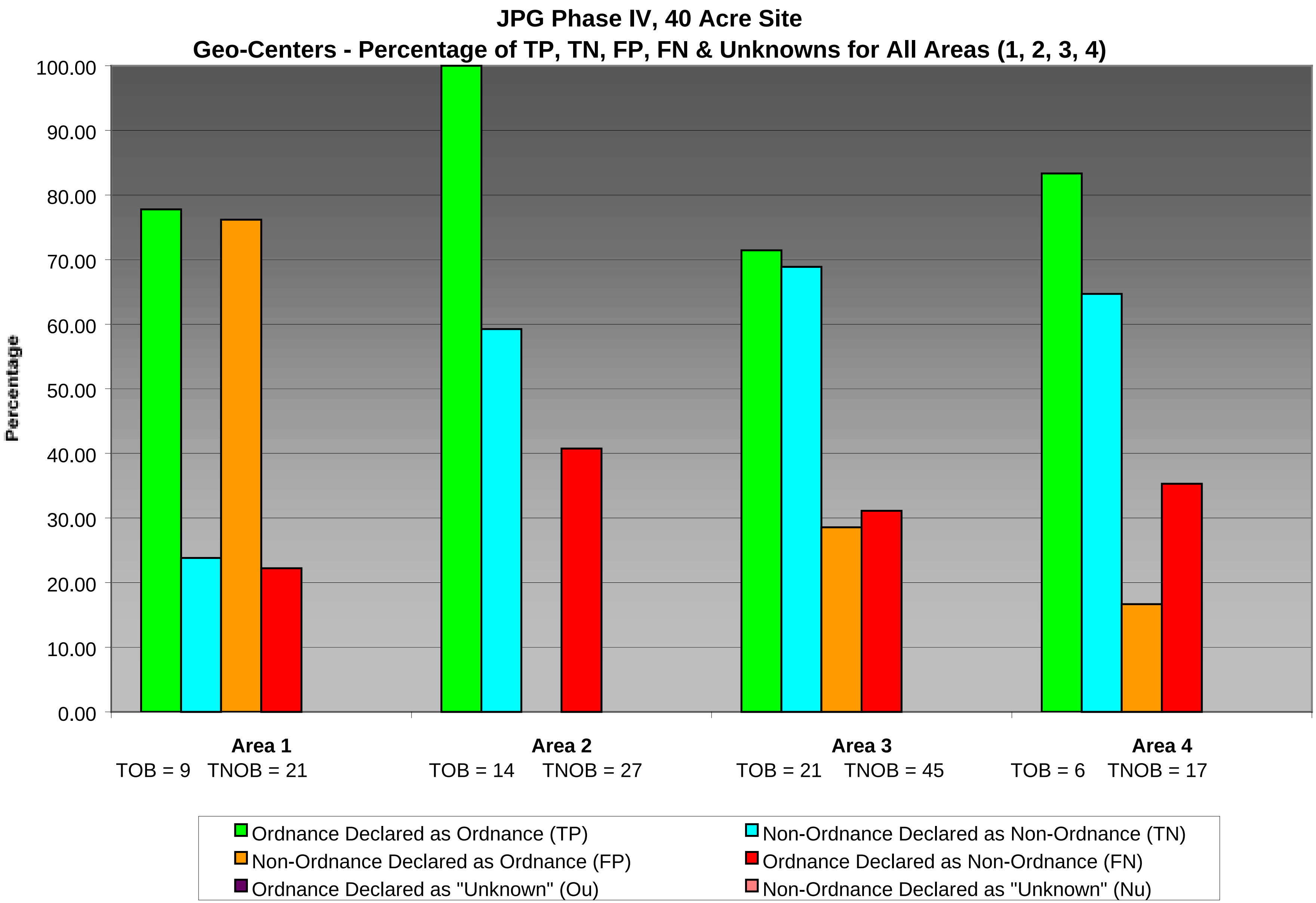
25 Targets missing from the Non-Ordnance Baseline

Geo-Centers

demonstrator	target	northing	easting	depth	type	confidence	weight	size	azimuth	declination	class	comments
026	1	4309722.70	641501.70	0.40	ordnance	0.890	not detemined	small	0	21	not detemined	
026	4	4309712.45	641508.14	-1.60	ordnance	0.890	not detemined	small	7	159	not detemined	
026	9	4309676.38	641524.96	0.60	ordnance	0.890	not detemined	small	293	18	not detemined	
026	14	4309700.03	641516.89	0.50	ordnance	0.890	not detemined	small	319	10	not detemined	
026	18	4309662.06	641508.74	0.20	ordnance	0.890	not detemined	small	333	38	not detemined	
026	22	4309648.86	641528.65	0.60	ordnance	0.890	not detemined	small	6	32	not detemined	
026	23	4309640.76	641533.11	0.40	ordnance	0.890	not detemined	small	12	46	not detemined	
026	24	4309633.70	641524.66	0.90	ordnance	0.890	not detemined	small	96	56	not detemined	
026	27	4309637.33	641494.33	0.40	ordnance	0.890	not detemined	small	340	70	not detemined	
026	29	4309639.57	641477.01	1.30	ordnance	0.890	not detemined	small	299	28	not detemined	
026	32	4309539.57	641651.14	0.60	ordnance	0.890	not detemined	small	38	59	not detemined	
026	35	4309533.29	641646.42	0.50	ordnance	0.890	not detemined	small	28	35	not detemined	
026	46	4309520.27	641636.63	0.10	ordnance	0.890	not detemined	small	1	29	not detemined	
026	47	4309518.96	641646.01	0.20	ordnance	0.890	not detemined	small	11	27	not detemined	
026	48	4309511.73	641648.62	0.40	ordnance	0.890	not detemined	small	324	35	not detemined	
026	49	4309505.22	641641.10	0.30	ordnance	0.890	not detemined	small	22	22	not detemined	
026	52	4309493.91	641651.48	0.30	ordnance	0.890	not detemined	small	295	38	not detemined	
026	55	4309481.43	641663.30	0.40	ordnance	0.890	not detemined	small	339	24	not detemined	
026	56	4309478.61	641677.07	0.90	ordnance	0.890	not detemined	small	25	10	not detemined	
026	57	4309487.49	641674.04	0.70	ordnance	0.890	not detemined	small	291	36	not detemined	
026	64	4309538.89	641668.48	-1.40	ordnance	0.890	not detemined	small	190	54	not detemined	
026	76	4309745.94	641596.09	0.90	ordnance	0.890	not detemined	small	315	99	not detemined	
026	77	4309738.56	641594.20	1.20	ordnance	0.890	not detemined	small	331	66	not detemined	
026	79	4309723.15	641592.11	0.90	ordnance	0.890	not detemined	small	182	64	not detemined	
026	91	4309731.88	641636.34	0.90	ordnance	0.890	not detemined	small	21	35	not detemined	
026	95	4309696.28	641636.28	2.20	ordnance	0.890	not detemined	small	262	54	not detemined	
026	98	4309720.18	641636.30	1.00	ordnance	0.890	not detemined	small	304	41	not detemined	
026	99	4309719.96	641645.36	0.70	ordnance	0.890	not detemined	small	193	77	not detemined	
026	101	4309733.47	641655.23	0.80	ordnance	0.890	not detemined	small	322	15	not detemined	
026	122	4309699.04	641666.67	1.70	ordnance	0.890	not detemined	small	306	30	not detemined	
026	125	4309707.77	641677.97	1.40	ordnance	0.890	not detemined	small	331	58	not detemined	
026	130	4309713.82	641693.27	1.80	ordnance	0.890	not detemined	small	246	47	not detemined	
026	131	4309718.27	641687.11	0.80	ordnance	0.890	not detemined	small	309	48	not detemined	
026	132	4309726.26	641690.09	2.80	ordnance	0.890	not detemined	medium	285	9	not detemined	
026	133	4309724.23	641697.04	1.60	ordnance	0.890	not detemined	small	87	46	not detemined	
026	141	4309583.90	641441.68	0.50	ordnance	0.890	not detemined	small	97	71	not detemined	
026	147	4309564.80	641443.93	0.30	ordnance	0.890	not detemined	small	345	39	not detemined	
026	152	4309557.98	641426.68	0.70	ordnance	0.890	not detemined	small	330	60	not detemined	
026	154	4309552.57	641432.50	0.40	ordnance	0.890	not detemined	small	355	65	not detemined	
026	31	4309543.45	641641.29	0.20	ordnance	0.890	not detemined	small	322	44	not detemined	
026	3	4309723.49	641489.96	0.20	ordnance	0.890	not detemined	small	279	45	not detemined	
026	36	4309531.07	641627.89	0.40	ordnance	0.890	not detemined	small	269	45	not detemined	
026	67	4309537.08	641680.90	0.20	ordnance	0.890	not detemined	small	283	26	not detemined	
026	90	4309731.48	641627.13	1.40	ordnance	0.890	not detemined	small	180	59	not detemined	
026	104	4309746.15	641659.91	1.90	ordnance	0.890	not detemined	small	210	78	not detemined	
026	139	4309588.37	641456.71	0.70	ordnance	0.890	not detemined	small	271	14	not detemined	
026	140	4309588.10	641447.88	1.10	ordnance	0.890	not detemined	small	263	34	not detemined	
026	160	4309533.94	641457.34	0.50	ordnance	0.890	not detemined	small	81	44	not detemined	
026	12	4309704.60	641533.33	0.40	ordnance	0.889	not detemined	small	293	10	not detemined	
026	88	4309739.79	641623.50	0.60	ordnance	0.888	not detemined	small	312	19	not detemined	
026	89	4309739.38	641631.78	0.60	ordnance	0.888	not detemined	small	348	100	not detemined	
026	149	4309557.23	641460.65	0.50	ordnance	0.888	not detemined	small	221	63	not detemined	
026	129	4309711.33	641704.34	0.60	ordnance	0.888	not detemined	small	27	29	not detemined	
026	68	4309530.70	641686.63	0.30	ordnance	0.886	not detemined	small	323	26	not detemined	
026	17	4309666.50	641517.38	0.00	ordnance	0.884	not detemined	small	81	149	not detemined	
026	142	4309581.78	641450.06	0.50	ordnance	0.884	not detemined	small	21	43	not detemined	
026	145	4309571.70	641434.74	0.20	ordnance	0.882	not detemined	small	25	5	not detemined	
026	63	4309526.94	641666.14	0.10	ordnance	0.881	not detemined	small	294	19	not detemined	
026	135	4309725.58	641705.75	1.80	ordnance	0.880	not detemined	small	22	22	not detemined	
026	2	4309714.72	641491.13	0.50	ordnance	0.878	not detemined	small	221	72	not detemined	
026	136	4309732.42	641703.43	1.30	ordnance	0.877	not detemined	small	328	5	not detemined	

026	53	4309502.13	641654.46	1.30	ordnance	0.868	not detemined	small	32	43	not detemined	
026	138	4309591.08	641465.64	0.80	ordnance	0.859	not detemined	small	39	67	not detemined	
026	83	4309721.05	641611.78	0.80	ordnance	0.852	not detemined	small	16	355	not detemined	
026	109	4309737.30	641680.23	2.70	ordnance	0.851	not detemined	medium	88	49	not detemined	
026	151	4309559.19	641438.97	0.80	ordnance	0.818	not detemined	small	17	62	not detemined	
026	60	4309497.79	641670.67	0.40	ordnance	0.818	not detemined	small	6	57	not detemined	
026	70	4309521.63	641686.13	0.40	ordnance	0.796	not detemined	small	13	7	not detemined	
026	21	4309647.79	641513.14	0.40	ordnance	0.794	not detemined	small	249	38	not detemined	
026	94	4309710.07	641634.08	1.90	ordnance	0.789	not detemined	small	25	57	not detemined	
026	123	4309707.43	641670.52	1.30	ordnance	0.774	not detemined	small	54	1	not detemined	
026	120	4309683.27	641646.86	1.50	ordnance	0.769	not detemined	small	44	104	not detemined	
026	102	4309740.66	641646.02	0.80	ordnance	0.753	not detemined	small	35	29	not detemined	
026	30	4309631.14	641481.16	0.70	ordnance	0.751	not detemined	small	33	6	not detemined	
026	87	4309752.12	641611.40	0.90	ordnance	0.741	not detemined	small	49	23	not detemined	
026	51	4309491.99	641640.43	1.20	ordnance	0.737	not detemined	small	123	93	not detemined	real weak and diffuse
026	126	4309695.10	641686.27	0.90	ordnance	0.736	not detemined	small	61	30	not detemined	
026	143	4309575.88	641458.81	0.60	ordnance	0.731	not detemined	small	55	5	not detemined	
026	58	4309485.96	641684.15	0.70	ordnance	0.726	not detemined	small	64	18	not detemined	
026	117	4309682.41	641623.27	1.20	ordnance	0.726	not detemined	small	67	30	not detemined	
026	15	4309698.16	641541.13	0.60	ordnance	0.726	not detemined	small	35	64	not detemined	
026	16	4309685.35	641538.48	1.40	ordnance	0.726	not detemined	small	75	22	not detemined	
026	78	4309731.32	641596.01	1.80	ordnance	0.726	not detemined	small	141	51	not detemined	
026	80	4309724.92	641583.68	0.40	ordnance	0.726	not detemined	small	45	14	not detemined	
026	148	4309565.40	641459.27	0.60	ordnance	0.726	not detemined	small	69	59	not detemined	
026	137	4309738.07	641699.60	3.90	ordnance	0.725	not detemined	large	150	355	not detemined	
026	40	4309531.61	641607.38	0.00	ordnance	0.724	not detemined	small	233	22	not detemined	
026	25	4309647.94	641494.91	0.50	ordnance	0.720	not detemined	small	47	19	not detemined	
026	118	4309681.46	641638.28	4.40	ordnance	0.715	not detemined	medium	157	119	not detemined	
026	42	4309518.17	641604.89	0.20	ordnance	0.712	not detemined	small	96	5	not detemined	
026	113	4309713.89	641647.61	4.30	ordnance	0.700	not detemined	small	23	148	not detemined	
026	106	4309744.70	641680.61	2.00	ordnance	0.699	not detemined	small	292	37	not detemined	
026	86	4309745.25	641608.31	1.00	ordnance	0.699	not detemined	small	294	34	not detemined	
026	65	4309547.09	641676.59	0.30	ordnance	0.688	not detemined	small	66	69	not detemined	
026	84	4309730.05	641610.97	1.20	ordnance	0.684	not detemined	small	314	24	not detemined	
026	110	4309721.73	641673.21	1.30	ordnance	0.684	not detemined	small	19	16	not detemined	
026	103	4309749.19	641637.01	1.10	ordnance	0.681	not detemined	small	26	20	not detemined	
026	121	4309691.65	641660.95	1.30	ordnance	0.672	not detemined	small	314	18	not detemined	
026	19	4309660.16	641525.29	0.50	ordnance	0.663	not detemined	small	340	14	not detemined	
026	41	4309525.66	641610.30	1.80	ordnance	0.663	not detemined	small	291	332	not detemined	
026	100	4309724.72	641654.05	0.80	ordnance	0.663	not detemined	small	355	359	not detemined	
026	111	4309721.85	641661.97	1.00	ordnance	0.663	not detemined	small	10	15	not detemined	
026	61	4309511.17	641664.40	0.50	ordnance	0.634	not detemined	small	342	339	not detemined	
026	74	4309750.91	641571.38	0.50	ordnance	0.631	not detemined	small	244	22	not detemined	
026	11	4309711.92	641524.55	4.60	ordnance	0.570	not detemined	large	113	5	not detemined	looks good manually moved up
026	85	4309737.76	641607.02	0.80	ordnance	0.548	not detemined	small	295	18	not detemined	real weak but representative - manually moved up
026	81	4309715.75	641601.88	1.00	ordnance	0.523	not detemined	small	208	56	not detemined	real weak but representative - manually moved up
026	43	4309512.93	641612.77	1.90	ordnance	0.499	not detemined	small	123	294	not detemined	real weak but representative-manually moved up
026	20	4309656.01	641500.36	0.30	ordnance	0.448	not detemined	small	25	330	not detemined	real weak but representative-manually moved up
026	26	4309636.74	641511.68	0.00	ordnance	0.110	not detemined	small	357	8	not detemined	weak signature - manually moved up
026	33	4309536.12	641637.05	1.10	ordnance	0.110	not detemined	small	72	269	not detemined	real weak but representative-manually moved up
026	39	4309517.60	641625.27	0.20	ordnance	0.110	not detemined	small	83	8	not detemined	real weak but representative-manually moved up

026	71	4309511.26	641685.85	0.30	ordnance	0.110	not detemined	small	50	38	not detemined	real weak but representative-manually moved up
026	144	4309576.94	641442.02	0.80	ordnance	0.110	not detemined	small	34	64	not detemined	real weak but representative - manually moved up
026	155	4309548.95	641445.84	-0.10	ordnance	0.110	not detemined	small	265	11	not detemined	real weak - manually moved up
026	108	4309737.95	641686.85	1.50	nonordnance	0.890	not detemined	small	343	20	not detemined	too large - manually moved down
026	93	4309713.13	641626.89	1.90	nonordnance	0.887	not detemined	small	15	24	not detemined	manually moved down
026	73	4309732.61	641580.44	2.90	nonordnance	0.878	not detemined	small	183	114	not detemined	obscured by background signal - manually moved down
026	107	4309743.43	641695.05	1.00	nonordnance	0.878	not detemined	unknown	336	163	not detemined	bad feature extraction - manually moved down
026	62	4309517.98	641669.52	0.10	nonordnance	0.814	not detemined	small	31	16	not detemined	manually moved down
026	115	4309694.87	641643.22	1.00	nonordnance	0.731	not detemined	unknown	308	292	not detemined	difuse - manually moved down
026	124	4309716.36	641670.84	2.40	nonordnance	0.728	not detemined	small	337	49	not detemined	manually moved down
026	13	4309684.84	641503.19	5.90	nonordnance	0.700	not detemined	large	256	52	not detemined	no clear signal - manually moved down
026	5	4309699.31	641487.30	0.40	nonordnance	0.684	not detemined	small	191	357	not detemined	weak/no mag - manually moved down
026	10	4309671.29	641533.85	1.60	nonordnance	0.681	not detemined	medium	32	4	not detemined	too big - maually moved down
026	92	4309721.19	641626.86	1.70	nonordnance	0.667	not detemined	small	354	60	not detemined	weak and diffuse - manually moved down
026	114	4309699.44	641657.94	1.00	nonordnance	0.663	not detemined	unknown	110	224	not detemined	bad feature extraction - manually moved down
026	127	4309707.40	641689.42	2.20	nonordnance	0.663	not detemined	small	132	25	not detemined	bad feature extraction - manually moved down
026	112	4309717.48	641654.64	2.20	nonordnance	0.663	not detemined	large	23	357	not detemined	too large - manually moved down
026	153	4309551.55	641418.82	0.40	nonordnance	0.578	not detemined	small	258	16	not detemined	
026	159	4309540.58	641449.22	0.10	nonordnance	0.549	not detemined	small	330	1	not detemined	
026	97	4309713.05	641641.11	1.50	nonordnance	0.544	not detemined	medium	198	90	not detemined	
026	28	4309648.35	641480.08	1.50	nonordnance	0.526	not detemined	small	104	44	not detemined	
026	8	4309689.96	641519.42	0.80	nonordnance	0.523	not detemined	small	207	43	not detemined	orientation bad
026	59	4309492.01	641680.96	0.80	nonordnance	0.523	not detemined	small	224	6	not detemined	
026	150	4309556.93	641450.20	0.60	nonordnance	0.523	not detemined	small	239	11	not detemined	
026	45	4309513.31	641635.27	0.40	nonordnance	0.522	not detemined	small	255	9	not detemined	
026	44	4309506.92	641625.36	0.30	nonordnance	0.503	not detemined	small	15	359	not detemined	
026	157	4309539.57	641422.28	0.10	nonordnance	0.499	not detemined	small	12	358	not detemined	
026	105	4309736.62	641672.71	1.00	nonordnance	0.467	not detemined	unknown	66	332	not detemined	
026	7	4309695.31	641497.25	0.00	nonordnance	0.455	not detemined	small	155	4	not detemined	
026	38	4309524.92	641621.87	0.00	nonordnance	0.448	not detemined	small	16	0	not detemined	
026	96	4309701.65	641650.21	2.00	nonordnance	0.425	not detemined	medium	48	0	not detemined	
026	82	4309712.38	641610.36	0.80	nonordnance	0.409	not detemined	small	82	5	not detemined	
026	66	4309543.17	641685.24	0.50	nonordnance	0.337	not detemined	small	81	352	not detemined	
026	116	4309688.47	641631.81	0.20	nonordnance	0.313	not detemined	small	207	59	not detemined	
026	119	4309674.72	641644.17	1.00	nonordnance	0.148	not detemined	unknown	285	235	not detemined	
026	128	4309706.08	641696.89	0.90	nonordnance	0.112	not detemined	small	261	351	not detemined	
026	6	4309707.48	641478.93	1.20	nonordnance	0.110	not detemined	small	82	99	not detemined	
026	34	4309542.76	641627.66	1.30	nonordnance	0.110	not detemined	small	150	260	not detemined	
026	37	4309527.77	641639.37	1.00	nonordnance	0.110	not detemined	unknown	325	270	not detemined	
026	50	4309500.51	641633.49	1.10	nonordnance	0.110	not detemined	small	36	349	not detemined	
026	54	4309488.64	641658.99	0.10	nonordnance	0.110	not detemined	small	322	248	not detemined	
026	69	4309529.65	641675.59	0.00	nonordnance	0.110	not detemined	small	159	38	not detemined	
026	72	4309741.85	641580.80	1.70	nonordnance	0.110	not detemined	small	200	319	not detemined	
026	75	4309753.53	641588.17	1.00	nonordnance	0.110	not detemined	unknown	347	355	not detemined	
026	134	4309719.03	641703.26	0.60	nonordnance	0.110	not detemined	small	225	292	not detemined	
026	146	4309566.49	641426.01	0.70	nonordnance	0.110	not detemined	small	193	35	not detemined	
026	156	4309543.94	641436.55	0.60	nonordnance	0.110	not detemined	unknown	31	133	not detemined	
026	158	4309535.24	641432.68	2.10	nonordnance	0.110	not detemined	small	156	15	not detemined	



%TP = (Correct Ordnance Declarations / TOB) x 100

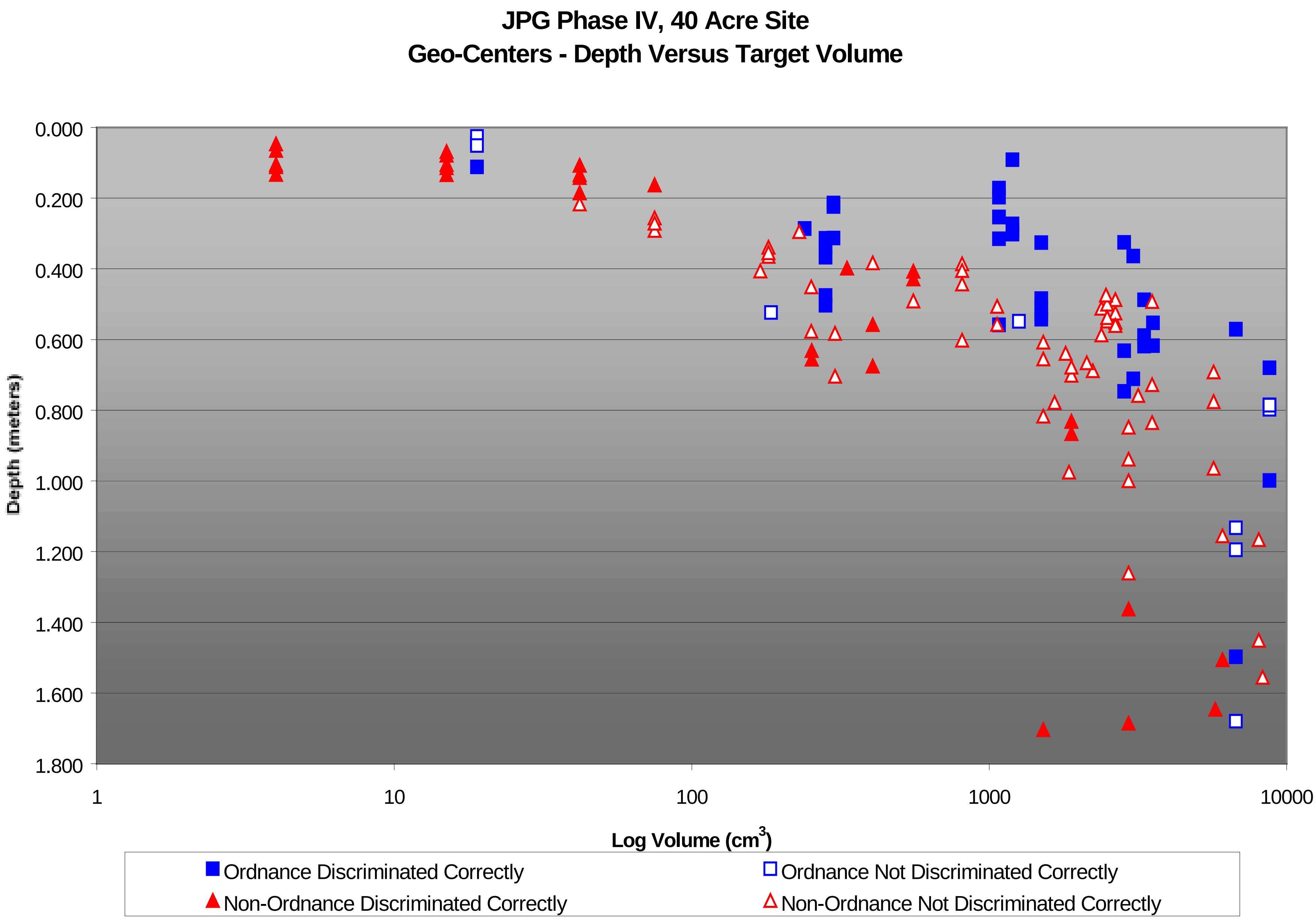
%TN = (Correct Non-Ordnance Declarations / TNOB) x 100

%FP = (Non-Ordnance Declared as Ordnance / TNOB) x 100

%Ou = (Ordnance Declared as Unknown / TOB) x 100

%Nu = (Non-Ordnance Declared as Unknown / TNOB) x 100

%FN = (Ordnance Declared as Non-Ordnance / TOB) x 100



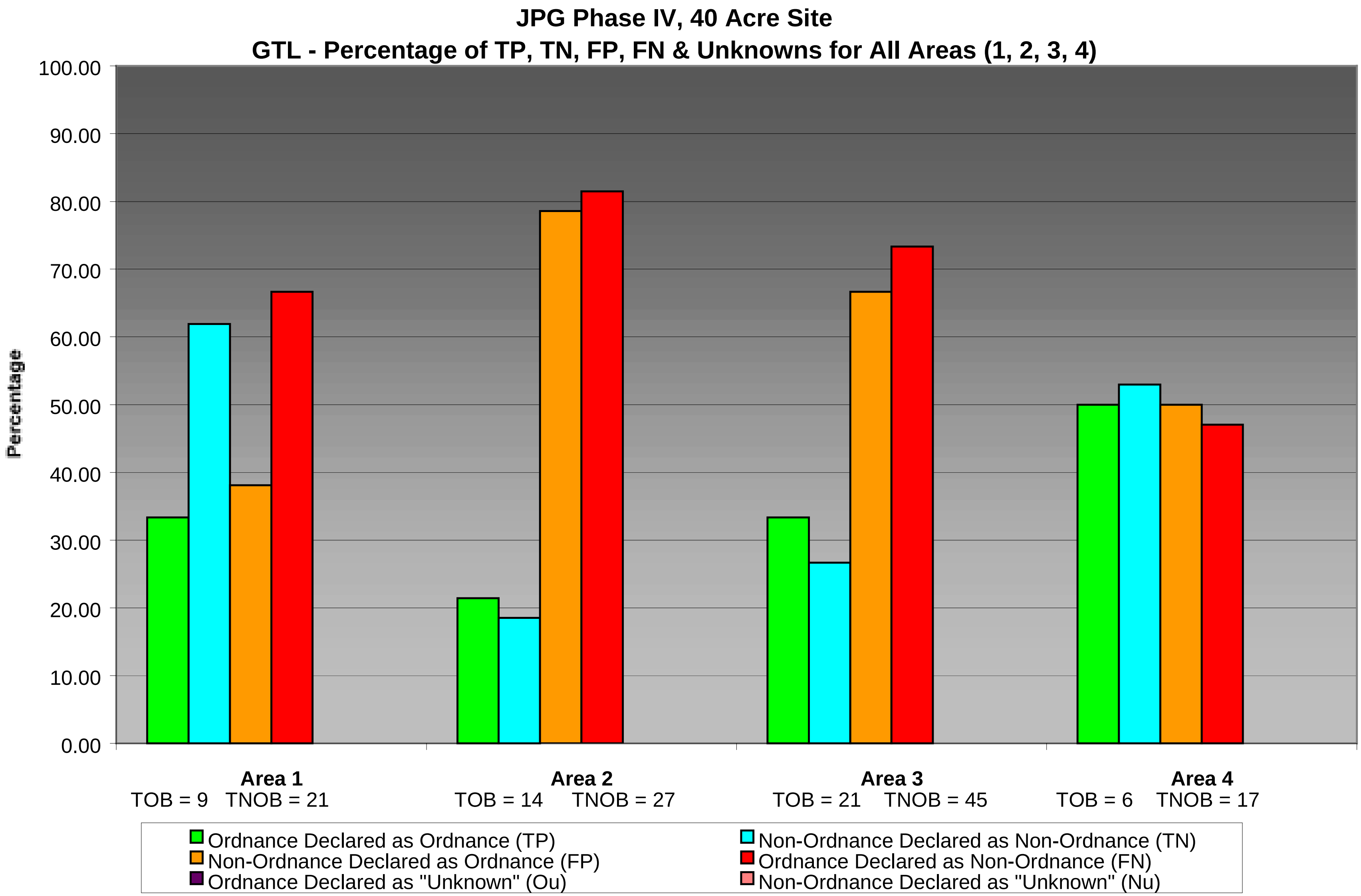
25 Targets missing from the Non-Ordnance Baseline

Geophysical Technology Limited

Demonstrator	Target	Easting	Northing	Depth	Type	Confidence	Weight	Size	Azimuth	Declination	Class	Comments	Depth
													Below Sensor
GTL	98	641636.30	4309720.18	0.8	ordnance	high	moderate	medium	138.2	17.43	unknown	proj or mortar	1.2
GTL	19	641525.29	4309660.16	1.12	ordnance	high	moderate	medium	-13.06	12.32	unknown	proj or mortar	1.52
GTL	141	641441.68	4309583.90	0.76	ordnance	high	moderate	medium	146.01	59.23	unknown	proj or mortar	1.16
GTL	35	641646.42	4309533.29	0.86	ordnance	high	moderate	medium	27.67	1.56	unknown	proj or mortar	1.26
GTL	22	641528.65	4309648.86	0.93	ordnance	high	moderate	medium	-169.99	1.32	unknown	proj or mortar	1.33
GTL	58	641684.15	4309485.96	0.87	ordnance	high	moderate	medium	-98.58	2.24	unknown	proj or mortar	1.27
GTL	11	641524.55	4309711.92	1.09	ordnance	high	moderate	medium	-31.26	34.11	unknown	proj or mortar	1.49
GTL	56	641677.07	4309478.61	1.11	ordnance	high	moderate	medium	-156.77	5.51	unknown	proj or mortar	1.51
GTL	15	641541.13	4309698.16	0.94	ordnance	high	moderate	medium	42.49	66.32	unknown	proj or mortar	1.34
GTL	134	641703.26	4309719.03	0.29	ordnance	high	moderate	medium	-117.67	58.56	unknown	proj or mortar	0.69
GTL	32	641651.14	4309539.57	0.96	ordnance	high	moderate	medium	30.83	52.01	unknown	proj or mortar	1.36
GTL	25	641494.91	4309647.94	0.88	ordnance	high	moderate	medium	-123	10.98	unknown	proj or mortar	1.28
GTL	140	641447.88	4309588.10	1.04	ordnance	high	moderate	medium	-113.82	7.1	unknown	proj or mortar	1.44
GTL	137	641699.60	4309738.07	0.84	ordnance	high	moderate	medium	-109.42	28.8	unknown	proj or mortar	1.24
GTL	13	641503.19	4309684.84	1.5	ordnance	high	light	small	153.46	7.23	20 mm proj		1.9
GTL	34	641627.66	4309542.76	0.22	ordnance	high	light	small	160.65	14.36	20 mm proj		0.62
GTL	75	641588.17	4309753.53	0.56	ordnance	high	light	small	0	90	20 mm proj		0.96
GTL	116	641631.81	4309688.47	0.06	ordnance	high	light	small	-123.5	16.63	20 mm proj		0.46
GTL	156	641436.55	4309543.94	0.56	ordnance	high	light	small	-31.7	41.93	20 mm proj		0.96
GTL	158	641432.68	4309535.24	2.07	ordnance	moderate	light	small	168.77	30.72	20 mm proj		2.47
GTL	138	641465.64	4309591.08	0.68	ordnance	moderate	moderate	medium	-132.45	4.56	unknown	proj or mortar	1.08
GTL	100	641654.05	4309724.72	1.06	ordnance	moderate	moderate	medium	174.36	19.67	unknown	proj or mortar	1.46
GTL	124	641670.84	4309716.36	1.02	ordnance	moderate	moderate	medium	-160.47	22.04	unknown	proj or mortar	1.42
GTL	77	641594.20	4309738.56	0.91	ordnance	moderate	moderate	medium	-17.57	24.39	unknown	proj or mortar	1.31
GTL	143	641458.81	4309575.88	0.91	ordnance	moderate	moderate	medium	-114.96	12.73	unknown	proj or mortar	1.31
GTL	108	641686.85	4309737.95	1.31	ordnance	moderate	moderate	medium	174.38	3.19	unknown	proj or mortar	1.71
GTL	122	641666.67	4309699.04	0.94	ordnance	moderate	moderate	medium	169.75	2.45	unknown	proj or mortar	1.34
GTL	132	641690.09	4309726.26	1	ordnance	moderate	moderate	medium	142.15	18.92	unknown	proj or mortar	1.4
GTL	135	641705.75	4309725.58	1.23	ordnance	moderate	moderate	medium	-141.01	28.66	unknown	proj or mortar	1.63
GTL	95	641636.28	4309696.28	1.47	ordnance	moderate	moderate	medium	-8.57	52.86	unknown	proj or mortar	1.87
GTL	36	641627.89	4309531.07	0.87	ordnance	moderate	moderate	medium	-118.95	25.47	unknown	proj or mortar	1.27
GTL	79	641592.11	4309723.15	0.72	ordnance	moderate	moderate	medium	-152.41	66.01	unknown	proj or mortar	1.12
GTL	57	641674.04	4309487.49	0.86	ordnance	moderate	moderate	medium	-70.29	12.79	unknown	proj or mortar	1.26
GTL	148	641459.27	4309565.40	0.8	ordnance	moderate	moderate	medium	131.83	10.8	unknown	proj or mortar	1.2
GTL	142	641450.06	4309581.78	0.73	ordnance	moderate	moderate	medium	-159.21	10.64	unknown	proj or mortar	1.13
GTL	151	641438.97	4309559.19	0.8	ordnance	moderate	moderate	medium	-106.95	82.26	unknown	proj or mortar	1.2
GTL	30	641481.16	4309631.14	0.89	ordnance	moderate	moderate	medium	-145.98	4	unknown	proj or mortar	1.29
GTL	14	641516.89	4309700.03	0.9	ordnance	moderate	moderate	medium	150	4.71	unknown	proj or mortar	1.3
GTL	120	641646.86	4309683.27	0.8	ordnance	moderate	moderate	medium	-153.53	20.88	unknown	proj or mortar	1.2
GTL	103	641637.01	4309749.19	1.01	ordnance	moderate	moderate	medium	29.74	4.1	unknown	proj or mortar	1.41
GTL	154	641432.50	4309552.57	0.7	ordnance	moderate	moderate	medium	-171.79	16.36	unknown	proj or mortar	1.1
GTL	147	641443.93	4309564.80	0.67	ordnance	moderate	moderate	medium	2.15	28.55	unknown	proj or mortar	1.07
GTL	8	641519.42	4309689.96	1.03	ordnance	moderate	moderate	medium	-159.6	14.32	unknown	proj or mortar	1.43
GTL	145	641434.74	4309571.70	0.68	ordnance	moderate	moderate	medium	-154.72	9.25	unknown	proj or mortar	1.08
GTL	24	641524.66	4309633.70	1.08	ordnance	low	moderate	medium	-76.89	1.12	projectile		1.48
GTL	28	641480.08	4309648.35	1.36	ordnance	low	moderate	medium	101.32	5.7	projectile		1.76
GTL	51	641640.43	4309491.99	1.48	ordnance	low	moderate	medium	-19.21	33.59	projectile		1.88
GTL	93	641626.89	4309713.13	1.34	ordnance	low	moderate	medium	0.78	15.55	projectile		1.74
GTL	97	641641.11	4309713.05	1.14	ordnance	low	moderate	medium	66.68	75.4	projectile		1.54
GTL	105	641672.71	4309736.62	0.81	ordnance	low	moderate	medium	168.69	22.28	projectile		1.21
GTL	10	641533.85	4309671.29	1.57	nonordnance	low	moderate	medium	-154.6	11.34	unknown		1.97
GTL	29	641477.01	4309639.57	1.22	nonordnance	low	moderate	medium	108.43	48.33	unknown		1.62
GTL	94	641634.08	4309710.07	1.29	nonordnance	low	moderate	medium	39.56	62.25	unknown		1.69
GTL	96	641650.21	4309701.65	1.33	nonordnance	low	moderate	medium	-138.27	17.98	unknown		1.73
GTL	107	641695.05	4309743.43	0.38	nonordnance	low	moderate	medium	-44.25	75.79	unknown		0.78
GTL	109	641680.23	4309737.30	1.57	nonordnance	low	moderate	medium	9.41	31.04	unknown		1.97
GTL	112	641654.64	4309717.48	1.05	nonordnance	low	moderate	medium	14.77	3.76	unknown		1.45
GTL	16	641538.48	4309685.35	1.15	nonordnance	low	moderate	medium	82.07	21.53	unknown		1.55
GTL	53	641654.46	4309502.13	1.18	nonordnance	low	moderate	medium	-148.31	45.81	unknown		1.58

GTL	78	641596.01	4309731.32	0.96	nonordnance	low	moderate	medium	163.01	17.42	unknown		1.36
GTL	92	641626.86	4309721.19	1.44	nonordnance	low	moderate	medium	-77.99	9.45	unknown		1.84
GTL	106	641680.61	4309744.70	1.33	nonordnance	low	moderate	medium	77.22	36.93	unknown		1.73
GTL	111	641661.97	4309721.85	0.92	nonordnance	low	moderate	medium	-13.82	79.23	unknown		1.32
GTL	114	641657.94	4309699.44	0.94	nonordnance	low	moderate	medium	-170.61	20.55	unknown		1.34
GTL	136	641703.43	4309732.42	1.24	nonordnance	low	moderate	medium	151.41	6.01	unknown		1.64
GTL	146	641426.01	4309566.49	0.77	nonordnance	low	moderate	medium	-175.23	37.8	unknown		1.17
GTL	72	641580.80	4309741.85	0.73	nonordnance	low	light	small	-171.17	35.09	unknown	plate/tube/disc	1.13
GTL	113	641647.61	4309713.89	0.34	nonordnance	low	light	small	0.21	18.62	unknown	plate/tube/disc	0.74
GTL	144	641442.02	4309576.94	0.81	nonordnance	low	light	small	157.2	11.35	unknown	plate/tube/disc	1.21
GTL	155	641445.84	4309548.95	0.38	nonordnance	low	light	small	-134.82	32.19	unknown	plate/tube/disc	0.78
GTL	159	641449.22	4309540.58	0.67	nonordnance	low	light	small	129.92	27.8	unknown	plate/tube/disc	1.07
GTL	5	641487.30	4309699.31	0.88	nonordnance	moderate	light	small	15.62	54.8	unknown	plate/tube/disc	1.28
GTL	7	641497.25	4309695.31	1.31	nonordnance	moderate	light	small	172.77	5.55	unknown	plate/tube/disc	1.71
GTL	33	641637.05	4309536.12	0.36	nonordnance	moderate	light	small	137.47	83.44	unknown	plate/tube/disc	0.76
GTL	38	641621.87	4309524.92	0.6	nonordnance	moderate	light	small	-161.95	21.31	unknown	plate/tube/disc	1
GTL	62	641669.52	4309517.98	0.46	nonordnance	moderate	light	small	-12.41	72.07	unknown	plate/tube/disc	0.86
GTL	74	641571.38	4309750.91	0.71	nonordnance	moderate	light	small	54.11	13.7	unknown	plate/tube/disc	1.11
GTL	157	641422.28	4309539.57	0.75	nonordnance	moderate	light	small	-33.25	82.65	unknown	plate/tube/disc	1.15
GTL	49	641641.10	4309505.22	0.71	nonordnance	moderate	moderate	medium	-119.68	66.26	unknown		1.11
GTL	104	641659.91	4309746.15	0.91	nonordnance	moderate	moderate	medium	-119.99	28.69	unknown		1.31
GTL	110	641673.21	4309721.73	1.13	nonordnance	moderate	moderate	medium	-159.42	1.9	unknown		1.53
GTL	59	641680.96	4309492.01	1.03	nonordnance	moderate	moderate	medium	-138.7	5.73	unknown		1.43
GTL	160	641457.34	4309533.94	0.95	nonordnance	moderate	moderate	medium	103.75	46.92	unknown		1.35
GTL	101	641655.23	4309733.47	0.96	nonordnance	moderate	moderate	medium	86.44	73.09	unknown		1.36
GTL	90	641627.13	4309731.48	1.06	nonordnance	moderate	moderate	medium	179.86	39.2	unknown		1.46
GTL	76	641596.09	4309745.94	0.86	nonordnance	moderate	moderate	medium	145.84	66.89	unknown		1.26
GTL	23	641533.11	4309640.76	0.78	nonordnance	moderate	moderate	medium	-166.01	7.06	unknown		1.18
GTL	150	641450.20	4309556.93	0.92	nonordnance	moderate	moderate	medium	-119.9	12.06	unknown		1.32
GTL	133	641697.04	4309724.23	0.99	nonordnance	moderate	moderate	medium	-154.89	77.49	unknown		1.39
GTL	149	641460.65	4309557.23	0.96	nonordnance	moderate	moderate	medium	-160.74	23.85	unknown		1.36
GTL	45	641635.27	4309513.31	0.84	nonordnance	moderate	moderate	medium	-113.81	1.17	unknown		1.24
GTL	31	641641.29	4309543.45	0.62	nonordnance	moderate	moderate	medium	-26.99	40.81	unknown		1.02
GTL	63	641666.14	4309526.94	0.46	nonordnance	moderate	moderate	medium	98.68	7.92	unknown		0.86
GTL	64	641668.48	4309538.89	0.53	nonordnance	moderate	moderate	medium	178.75	14.65	unknown		0.93
GTL	99	641645.36	4309719.96	0.6	nonordnance	moderate	moderate	medium	-179.16	40.23	unknown		1
GTL	12	641533.33	4309704.60	0.85	nonordnance	moderate	moderate	medium	40.83	69.63	unknown		1.25
GTL	17	641517.38	4309666.50	0.57	nonordnance	moderate	moderate	medium	-143.42	19.21	unknown		0.97
GTL	20	641500.36	4309656.01	0.86	nonordnance	moderate	moderate	medium	-165.14	17.5	unknown		1.26
GTL	21	641513.14	4309647.79	0.74	nonordnance	moderate	moderate	medium	7.06	62.94	unknown		1.14
GTL	39	641625.27	4309517.60	0.57	nonordnance	moderate	moderate	medium	-7.9	65.84	unknown		0.97
GTL	40	641607.38	4309531.61	0.54	nonordnance	moderate	moderate	medium	6.68	60.96	unknown		0.94
GTL	43	641612.77	4309512.93	0.76	nonordnance	moderate	moderate	medium	-145.82	0.86	unknown		1.16
GTL	44	641625.36	4309506.92	0.76	nonordnance	moderate	moderate	medium	-55.27	83.3	unknown		1.16
GTL	46	641636.63	4309520.27	0.74	nonordnance	moderate	moderate	medium	-162.13	28.84	unknown		1.14
GTL	47	641646.01	4309518.96	0.61	nonordnance	moderate	moderate	medium	-149.36	26.47	unknown		1.01
GTL	52	641651.48	4309493.91	0.7	nonordnance	moderate	moderate	medium	108.57	11.72	unknown		1.1
GTL	54	641658.99	4309488.64	1.21	nonordnance	moderate	moderate	medium	-132.58	14.83	unknown		1.61
GTL	55	641663.30	4309481.43	0.99	nonordnance	moderate	moderate	medium	164.66	13.14	unknown		1.39
GTL	60	641670.67	4309497.79	1.15	nonordnance	moderate	moderate	medium	9.18	40.77	unknown		1.55
GTL	61	641664.40	4309511.17	0.93	nonordnance	moderate	moderate	medium	168.71	23.49	unknown		1.33
GTL	67	641680.90	4309537.08	0.6	nonordnance	moderate	moderate	medium	93.96	10.17	unknown		1
GTL	68	641686.63	4309530.70	0.65	nonordnance	moderate	moderate	medium	77.83	81.9	unknown		1.05
GTL	71	641685.85	4309511.26	0.59	nonordnance	moderate	moderate	medium	-163.29	8.7	unknown		0.99
GTL	80	641583.68	4309724.92	0.47	nonordnance	moderate	moderate	medium	-12.75	75.88	unknown		0.87
GTL	81	641601.88	4309715.75	0.65	nonordnance	moderate	moderate	medium	4.3	61.44	unknown		1.05
GTL	82	641610.36	4309712.38	0.66	nonordnance	moderate	moderate	medium	-38.43	65.75	unknown		1.06
GTL	83	641611.78	4309721.05	0.93	nonordnance	moderate	moderate	medium	-172.5	29.16	unknown		1.33
GTL	85	641607.02	4309737.76	0.98	nonordnance	moderate	moderate	medium	-41.93	30.33	unknown		1.38
GTL	88	641623.50	4309739.79	0.64	nonordnance	moderate	moderate	medium	-40.08	4.14	unknown		1.04
GTL	102	641646.02	4309740.66	0.83	nonordnance	moderate	moderate	medium	-161.9	19.34	unknown		1.23
GTL	118	641638.28	4309681.46	0.12	nonordnance	moderate	moderate	medium	-0.15	67.75	unknown		0.52
GTL	123	641670.52	4309707.43	0.67	nonordnance	moderate	moderate	medium	-40.5	77.76	unknown		1.07
GTL	1	641501.70	4309722.70	0.8	nonordnance	moderate	moderate	medium	-23.35	85.01	unknown		1.2

GTL	3	641489.96	4309723.49	0.63	nonordnance	moderate	moderate	medium	-6.52	74.54	unknown			1.03
GTL	4	641508.14	4309712.45	0.69	nonordnance	moderate	moderate	medium	-149.14	22.71	unknown			1.09
GTL	42	641604.89	4309518.17	0.57	nonordnance	moderate	moderate	medium	111.07	11.31	unknown			0.97
GTL	65	641676.59	4309547.09	0.66	nonordnance	moderate	moderate	medium	108.87	2.35	unknown			1.06
GTL	87	641611.40	4309752.12	0.93	nonordnance	moderate	moderate	medium	-119.6	1.92	unknown			1.33
GTL	89	641631.78	4309739.38	0.56	nonordnance	moderate	moderate	medium	0.6	62.83	unknown			0.96
GTL	129	641704.34	4309711.33	0.78	nonordnance	moderate	moderate	medium	35.91	57.18	unknown			1.18
GTL	6	641478.93	4309707.48	0.83	nonordnance	high	light	medium	-154.76	35.44	unknown	disc		1.23
GTL	37	641639.37	4309527.77	0.64	nonordnance	high	light	medium	179.47	47.02	unknown	disc		1.04
GTL	73	641580.44	4309732.61	1.98	nonordnance	high	light	medium	-10.69	22.94	unknown	disc		2.38
GTL	115	641643.22	4309694.87	1.75	nonordnance	high	light	medium	-131.71	29.27	unknown	disc		2.15
GTL	117	641623.27	4309682.41	0.92	nonordnance	high	moderate	medium	-92.67	8.05	unknown			1.32
GTL	27	641494.33	4309637.33	0.84	nonordnance	high	moderate	medium	-34.11	81.66	unknown			1.24
GTL	18	641508.74	4309662.06	0.63	nonordnance	high	moderate	medium	160.67	12.73	unknown			1.03
GTL	126	641686.27	4309695.10	0.67	nonordnance	high	moderate	medium	71.84	7.82	unknown			1.07
GTL	152	641426.68	4309557.98	0.96	nonordnance	high	moderate	medium	-20.59	56.6	unknown			1.36
GTL	9	641524.96	4309676.38	0.89	nonordnance	high	moderate	medium	106.32	4.77	unknown			1.29
GTL	139	641456.71	4309588.37	0.86	nonordnance	high	moderate	medium	-90.26	7.42	unknown			1.26
GTL	130	641693.27	4309713.82	0.85	nonordnance	high	moderate	medium	24.99	35.21	unknown			1.25
GTL	91	641636.34	4309731.88	0.84	nonordnance	high	moderate	medium	-37.32	77.98	unknown			1.24
GTL	48	641648.62	4309511.73	0.79	nonordnance	high	moderate	medium	143.84	16.55	unknown			1.19
GTL	131	641687.11	4309718.27	0.85	nonordnance	high	moderate	medium	97.18	16.1	unknown			1.25
GTL	125	641677.97	4309707.77	0.67	nonordnance	high	moderate	medium	-104.01	82.35	unknown			1.07
GTL	153	641418.82	4309551.55	0.75	nonordnance	high	moderate	medium	-103.75	21.2	unknown			1.15
GTL	2	641491.13	4309714.72	0.74	nonordnance	high	moderate	medium	-165.65	35.59	unknown			1.14
GTL	41	641610.30	4309525.66	0.87	nonordnance	high	moderate	medium	51.11	71.43	unknown	plate		1.27
GTL	69	641675.59	4309529.65	0.75	nonordnance	high	moderate	medium	0.24	69.14	unknown	plate		1.15
GTL	70	641686.13	4309521.63	0.92	nonordnance	high	moderate	medium	-64.98	82.51	unknown	plate		1.32
GTL	84	641610.97	4309730.05	0.95	nonordnance	high	moderate	medium	23.32	75.28	unknown	plate		1.35
GTL	119	641644.17	4309674.72	-0.23	nonordnance	high	moderate	medium	2.42	66.77	unknown	plate		0.17
GTL	121	641660.95	4309691.65	1.03	nonordnance	high	moderate	medium	167.51	43.9	unknown	plate		1.43
GTL	127	641689.42	4309707.40	1.28	nonordnance	high	moderate	medium	23.39	78.27	unknown	plate		1.68
GTL	26	641511.68	4309636.74	1.01	nonordnance	high	moderate	medium	-13.52	77.41	unknown	plate+discs		1.41
GTL	50	641633.49	4309500.51	0.99	nonordnance	high	moderate	medium	-78.8	77.32	unknown	plate+discs		1.39
GTL	66	641685.24	4309543.17	0.84	nonordnance	high	moderate	medium	-89.02	16.03	unknown	plate+discs		1.24
GTL	86	641608.31	4309745.25	1.09	nonordnance	high	moderate	medium	17.11	73.31	unknown	plate+discs		1.49
GTL	128	641696.89	4309706.08	0.99	nonordnance	high	moderate	medium	18.96	81.4	unknown	plate+discs		1.39



%TP = (Correct Ordnance Declarations / TOB) x 100

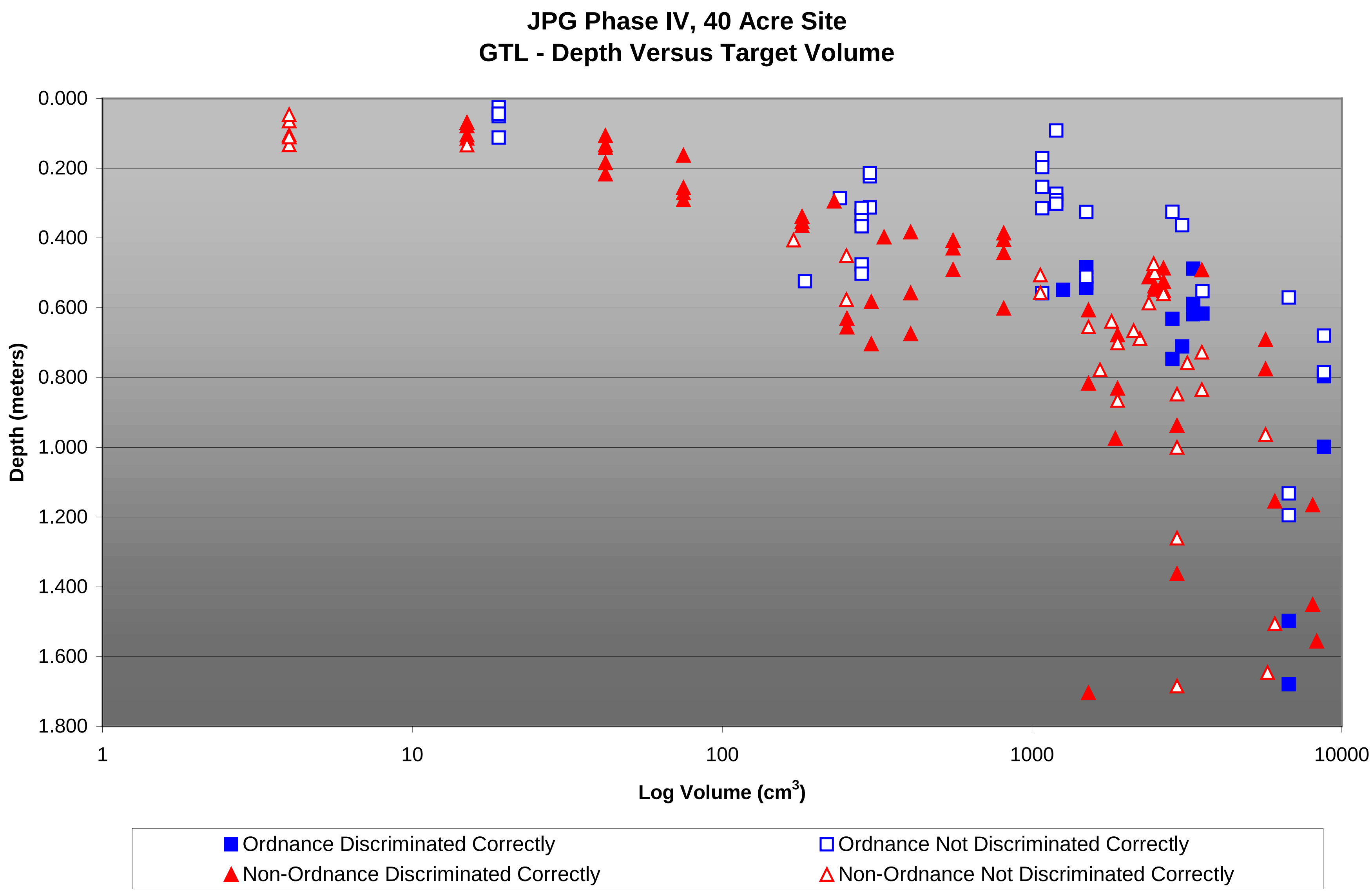
%TN = (Correct Non-Ordnance Declarations / TNOB) x 100

%FP = (Non-Ordnance Declared as Ordnance / TNOB) x 100

%Ou = (Ordnance Declared as Unknown / TOB) x 100

%Nu = (Non-Ordnance Declared as Unknown / TNOB) x 100

%FN = (Ordnance Declared as Non-Ordnance / TOB) x 100



25 Targets missing from the Non-Ordnance Baseline

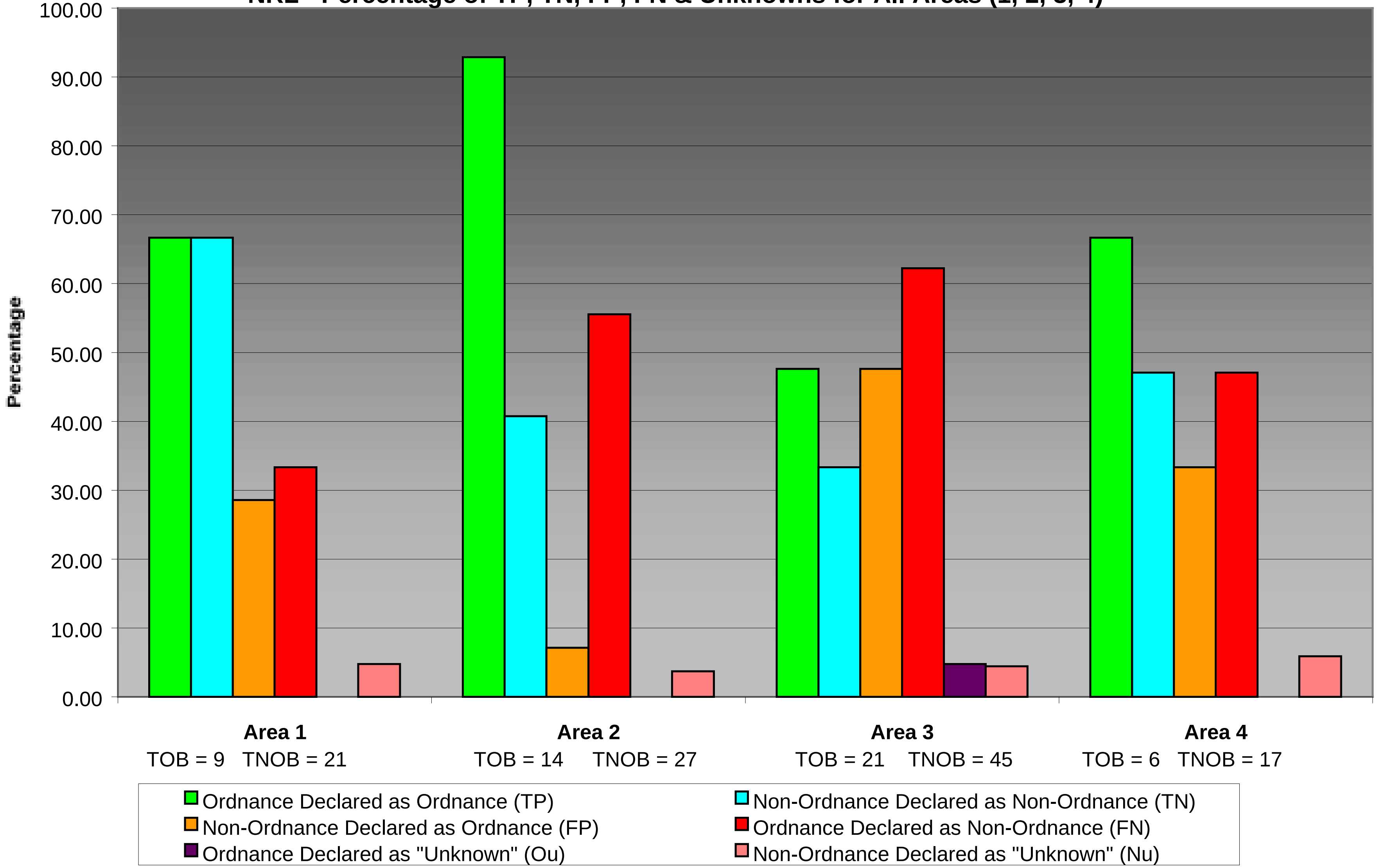
Naval Research Laboratory

rank	target	northing	easting	depth	type	confidence	weight	size	azimuth	declination	class	comments
1	1	4309722.70	641501.70	0.56	ordnance	moderate		medium	135	0	projectile	105mm
2	8	4309689.96	641519.42	0.93	ordnance	moderate		medium	315	0	projectile	152/155mm
3	20	4309656.01	641500.36	0.4	ordnance	moderate		small	0	0	projectile	57mm
4	21	4309647.79	641513.14	0.55	ordnance	moderate		small	45	0	mortar	81mm
5	25	4309647.94	641494.91	0.86	ordnance	moderate		medium	45	0	mortar	4.2"
6	27	4309637.33	641494.33	0.58	ordnance	moderate		medium	45	0	projectile	155mm
7	32	4309539.57	641651.14	0.94	ordnance	moderate		medium	45	0	mortar	4.2"
8	39	4309517.60	641625.27	0.35	ordnance	moderate		small	90	0	projectile	57mm
9	42	4309518.17	641604.89	0.35	ordnance	moderate		small	90	0	mortar	81mm
10	43	4309512.93	641612.77	0.44	ordnance	moderate		small	45	0	projectile	57mm
11	46	4309520.27	641636.63	0.31	ordnance	moderate		medium	0	0	projectile	105mm (Illumination case)
12	51	4309491.99	641640.43	1.34	ordnance	moderate		medium	315	0	mortar	4.2"
13	55	4309481.43	641663.30	0.7	ordnance	moderate		small	0	0	mortar	81mm (Illumination case)
14	66	4309543.17	641685.24	0.61	ordnance	moderate		small	270	0	mortar	81mm
15	71	4309511.26	641685.85	0.37	ordnance	moderate		small	135	0	projectile	57mm
16	98	4309720.18	641636.30	0.68	ordnance	moderate		medium	90	0	projectile	105mm
17	120	4309683.27	641646.86	0.54	ordnance	moderate		medium	30	0	mortar	4.2"
18	147	4309564.80	641443.93	0.51	ordnance	moderate		small	0	0	mortar	81mm
19	149	4309557.23	641460.65	0.74	ordnance	moderate		medium	45	0	projectile	155mm
20	3	4309723.49	641489.96	0.28	ordnance	moderate		small	90	0	mortar	81mm
21	15	4309698.16	641541.13	0.71	ordnance	moderate		medium	45	0	mortar	4.2"
22	18	4309662.06	641508.74	0.33	ordnance	moderate		small	45	0	mortar	60mm
23	23	4309640.76	641533.11	0.56	ordnance	moderate		small	90	0	mortar	81mm (illumination case)
24	33	4309536.12	641637.05	0.14	ordnance	moderate		small	135	-45	projectile	20mm
25	47	4309518.96	641646.01	0.39	ordnance	moderate		small	0	0	projectile	76mm
26	58	4309485.96	641684.15	1.02	ordnance	moderate		medium	0	0	projectile	155mm
27	67	4309537.08	641680.90	0.22	ordnance	moderate		small	270	0	mortar	60mm
28	87	4309752.12	641611.40	0.46	ordnance	moderate		small	0	0	mortar	81mm
29	88	4309739.79	641623.50	0.31	ordnance	moderate		small	0	0	projectile	76mm
30	89	4309739.38	641631.78	0.35	ordnance	moderate		small	0	0	mortar	81mm
31	90	4309731.48	641627.13	0.73	ordnance	moderate		medium	90	0	projectile	152mm
32	95	4309696.28	641636.28	0.61	ordnance	moderate		small	45	0	mortar	81mm (Illumination case)
33	102	4309740.66	641646.02	0.52	ordnance	moderate		small	135	0	projectile	76mm
34	118	4309681.46	641638.28	0.37	ordnance	moderate		small	45	0	projectile	57mm
35	119	4309674.72	641644.17	0.56	ordnance	moderate		small	0	0	mortar	81mm
36	123	4309707.43	641670.52	0.43	ordnance	moderate		small	45	0	mortar	81mm (Illumination case)
37	129	4309711.33	641704.34	0.45	ordnance	moderate		medium	65	0	projectile	105mm
38	136	4309732.42	641703.43	0.81	ordnance	moderate		small	0	0	mortar	81mm (illumination case)
39	151	4309559.19	641438.97	0.63	ordnance	moderate		medium	0	0	projectile	105mm
40	152	4309557.98	641426.68	0.62	ordnance	moderate		medium	0	0	mortar	4.2"
41	154	4309552.57	641432.50	0.56	ordnance	moderate		medium	90	0	projectile	105mm
42	157	4309539.57	641422.28	0.2	ordnance	moderate		small	30	0	projectile	20mm
43	160	4309533.94	641457.34	0.78	ordnance	moderate		medium	90	0	projectile	155mm
44	31	4309543.45	641641.29	0.28	ordnance	low		small	0	0	mortar	81mm
45	35	4309533.29	641646.42	0.67	ordnance	low		medium	45	0	projectile	105mm
46	40	4309531.61	641607.38	0.29	ordnance	low		small	90	0	mortar	60mm
47	50	4309500.51	641633.49	0.64	ordnance	low		small	90	0	projectile	76mm
48	52	4309493.91	641651.48	0.29	ordnance	low		medium	0	0	projectile	105mm (Illumination case)
49	56	4309478.61	641677.07	0.93	ordnance	low		medium	0	0	projectile	152mm
50	60	4309497.79	641670.67	0.77	ordnance	low		small	90	0	mortar	81mm (Illumination case)
51	61	4309511.17	641664.40	0.3	ordnance	low		small	270	0	projectile	57mm
52	63	4309526.94	641666.14	0.28	ordnance	low		small	90	0	mortar	81mm (Illumination case)
53	68	4309530.70	641686.63	0.38	ordnance	low		small	315	0	projectile	57mm
54	73	4309732.61	641580.44	0.04	ordnance	low		small	0	-45	projectile	20mm
55	74	4309750.91	641571.38	0.11	ordnance	low		small	45	0	projectile	20mm
56	75	4309753.53	641588.17	0.38	ordnance	low		small	90	0	projectile	20mm
57	76	4309745.94	641596.09	0.65	ordnance	low		medium	45	0	projectile	152mm
58	81	4309715.75	641601.88	0.31	ordnance	low		small	90	0	projectile	57mm
59	83	4309721.05	641611.78	0.43	ordnance	low		small	135	0	projectile	57mm
60	86	4309745.25	641608.31	0.35	ordnance	low		small	45	0	projectile	57mm

61	113	4309713.89	641647.61	0.5	ordnance	low		small	90	0	projectile	57mm
62	117	4309682.41	641623.27	0.74	ordnance	low		medium	90	0	projectile	155mm
63	130	4309713.82	641693.27	0.62	ordnance	low		medium	90	0	projectile	155mm
64	131	4309718.27	641687.11	0.54	ordnance	low		medium	90	0	mortar	4.2"
65	137	4309738.07	641699.60	0.81	ordnance	low		medium	60	0	mortar	4.2"
66	138	4309591.08	641465.64	0.67	ordnance	low		small	90	0	projectile	76mm
67	141	4309583.90	641441.68	0.52	ordnance	low		small	45	0	mortar	81mm
68	142	4309581.78	641450.06	0.62	ordnance	low		medium	30	0	mortar	4.2"
69	155	4309548.95	641445.84	0.15	ordnance	low		small	120	0	projectile	20mm
70	159	4309540.58	641449.22	0.24	ordnance	low		small	135	0	projectile	20mm
71	7	4309695.31	641497.25	0.15	ordnance	low		small	135	0	projectile	20mm
72	17	4309666.50	641517.38	0.23	ordnance	low		small	45	0	mortar	60mm
73	37	4309527.77	641639.37	0.44	ordnance	low		small	0	0	projectile	20mm
74	156	4309543.94	641436.55	unknown	unknown	low						
75	13	4309684.84	641503.19	unknown	unknown	low						
76	116	4309688.47	641631.81	unknown	unknown	low						
77	34	4309542.76	641627.66	unknown	unknown	low						
78	72	4309741.85	641580.80	unknown	unknown	low						
79	115	4309694.87	641643.22	unknown	unknown	low						
80	53	4309502.13	641654.46	1.27	nonordnance	low						
81	54	4309488.64	641658.99	1.31	nonordnance	low						
82	64	4309538.89	641668.48	0.33	nonordnance	low						
83	78	4309731.32	641596.01	0.77	nonordnance	low						
84	80	4309724.92	641583.68	0.2	nonordnance	low						
85	92	4309721.19	641626.86	1.17	nonordnance	low						
86	94	4309710.07	641634.08	1.46	nonordnance	low						
87	97	4309713.05	641641.11	1.37	nonordnance	low						
88	104	4309746.15	641659.91	0.49	nonordnance	low						
89	105	4309736.62	641672.71	2.18	nonordnance	low						
90	107	4309743.43	641695.05	1.48	nonordnance	low						
91	124	4309716.36	641670.84	0.57	nonordnance	low						
92	153	4309551.55	641418.82	0.48	nonordnance	low						
93	158	4309535.24	641432.68	0.04	nonordnance	low						
94	5	4309699.31	641487.30	0.05	nonordnance	low						
95	19	4309660.16	641525.29	0.68	nonordnance	low						
96	146	4309566.49	641426.01	0.63	nonordnance	low						
97	91	4309731.88	641636.34	0.66	nonordnance	moderate						
98	99	4309719.96	641645.36	0.42	nonordnance	moderate						
99	132	4309726.26	641690.09	1.05	nonordnance	moderate						
100	135	4309725.58	641705.75	0.92	nonordnance	moderate						
101	14	4309700.03	641516.89	0.75	nonordnance	moderate						
102	22	4309648.86	641528.65	0.64	nonordnance	moderate						plate
103	24	4309633.70	641524.66	1.08	nonordnance	moderate						
104	28	4309648.35	641480.08	1.58	nonordnance	moderate						
105	36	4309531.07	641627.89	0.6	nonordnance	moderate						
106	44	4309506.92	641625.36	0.46	nonordnance	moderate						plate
107	49	4309505.22	641641.10	0.52	nonordnance	moderate						
108	57	4309487.49	641674.04	0.71	nonordnance	moderate						plate-like
109	59	4309492.01	641680.96	0.89	nonordnance	moderate						
110	65	4309547.09	641676.59	0.44	nonordnance	moderate						
111	84	4309730.05	641610.97	0.44	nonordnance	moderate						
112	85	4309737.76	641607.02	0.34	nonordnance	moderate						
113	101	4309733.47	641655.23	0.58	nonordnance	moderate						
114	106	4309744.70	641680.61	1.14	nonordnance	moderate						
115	109	4309737.30	641680.23	2.45	nonordnance	moderate						
116	111	4309721.85	641661.97	1.45	nonordnance	moderate						
117	114	4309699.44	641657.94	1.21	nonordnance	moderate						plate-like
118	127	4309707.40	641689.42	0.85	nonordnance	moderate						
119	128	4309706.08	641696.89	0.79	nonordnance	moderate						
120	133	4309724.23	641697.04	0.64	nonordnance	moderate						
121	134	4309719.03	641703.26	0.84	nonordnance	moderate						
122	139	4309588.37	641456.71	1.01	nonordnance	moderate						
123	143	4309575.88	641458.81	0.9	nonordnance	moderate						
124	144	4309576.94	641442.02	0.26	nonordnance	moderate						

125	145	4309571.70	641434.74	0.43	nonordnance	moderate						
126	148	4309565.40	641459.27	0.67	nonordnance	moderate						
127	2	4309714.72	641491.13	0.44	nonordnance	moderate						
128	4	4309712.45	641508.14	0.34	nonordnance	moderate						
129	6	4309707.48	641478.93	0.28	nonordnance	moderate						small plate
130	9	4309676.38	641524.96	0.73	nonordnance	moderate						
131	16	4309685.35	641538.48	1.16	nonordnance	moderate						
132	26	4309636.74	641511.68	0.38	nonordnance	moderate						
133	29	4309639.57	641477.01	1.67	nonordnance	moderate						
134	30	4309631.14	641481.16	0.73	nonordnance	moderate			45	0		pipe-like
135	38	4309524.92	641621.87	0.11	nonordnance	moderate			0	0		pipe-like
136	41	4309525.66	641610.30	0.65	nonordnance	moderate						
137	45	4309513.31	641635.27	0.49	nonordnance	moderate			45	0		pipe-like
138	48	4309511.73	641648.62	0.52	nonordnance	moderate						
139	62	4309517.98	641669.52	0.11	nonordnance	moderate						plate
140	69	4309529.65	641675.59	0.6	nonordnance	moderate						
141	70	4309521.63	641686.13	0.63	nonordnance	moderate						
142	77	4309738.56	641594.20	0.68	nonordnance	moderate						
143	79	4309723.15	641592.11	0.3	nonordnance	moderate						
144	82	4309712.38	641610.36	0.45	nonordnance	moderate						
145	93	4309713.13	641626.89	1.57	nonordnance	moderate						
146	100	4309724.72	641654.05	0.75	nonordnance	moderate						
147	122	4309699.04	641666.67	0.72	nonordnance	moderate						
148	125	4309707.77	641677.97	0.51	nonordnance	moderate						
149	126	4309695.10	641686.27	0.53	nonordnance	moderate						
150	140	4309588.10	641447.88	1.12	nonordnance	moderate						
151	150	4309556.93	641450.20	0.72	nonordnance	moderate						
152	10	4309671.29	641533.85	1.82	nonordnance	high						
153	11	4309711.92	641524.55	1.36	nonordnance	high						
154	12	4309704.60	641533.33	0.46	nonordnance	high						
155	96	4309701.65	641650.21	1.81	nonordnance	high						
156	103	4309749.19	641637.01	0.87	nonordnance	high						
157	108	4309737.95	641686.85	1.23	nonordnance	high						
158	110	4309721.73	641673.21	1.46	nonordnance	high						
159	112	4309717.48	641654.64	2.61	nonordnance	high			90	0		pipe-like
160	121	4309691.65	641660.95	0.52	nonordnance	high						plate

JPG Phase IV, 40 Acre Site
NRL - Percentage of TP, TN, FP, FN & Unknowns for All Areas (1, 2, 3, 4)



%TP = (Correct Ordnance Declarations / TOB) x 100

%TN = (Correct Non-Ordnance Declarations / TNOB) x 100

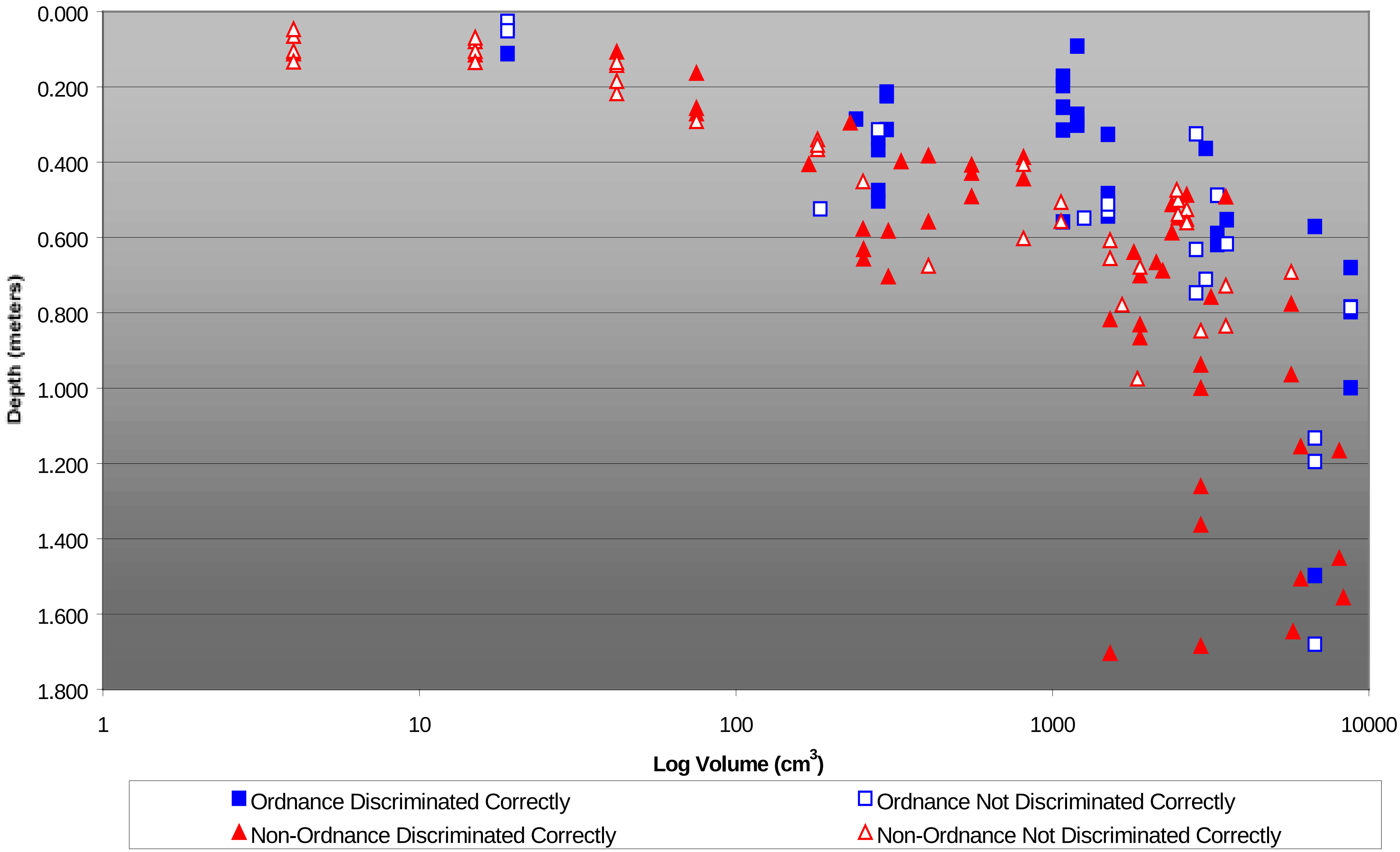
%FP = (Non-Ordnance Declared as Ordnance / TNOB) x 100

%Ou = (Ordnance Declared as Unknown / TOB) x 100

%Nu = (Non-Ordnance Declared as Unknown / TNOB) x 100

%FN = (Ordnance Declared as Non-Ordnance / TOB) x 100

JPG Phase IV, 40 Acre Site
NRL - Depth Versus Target Volume



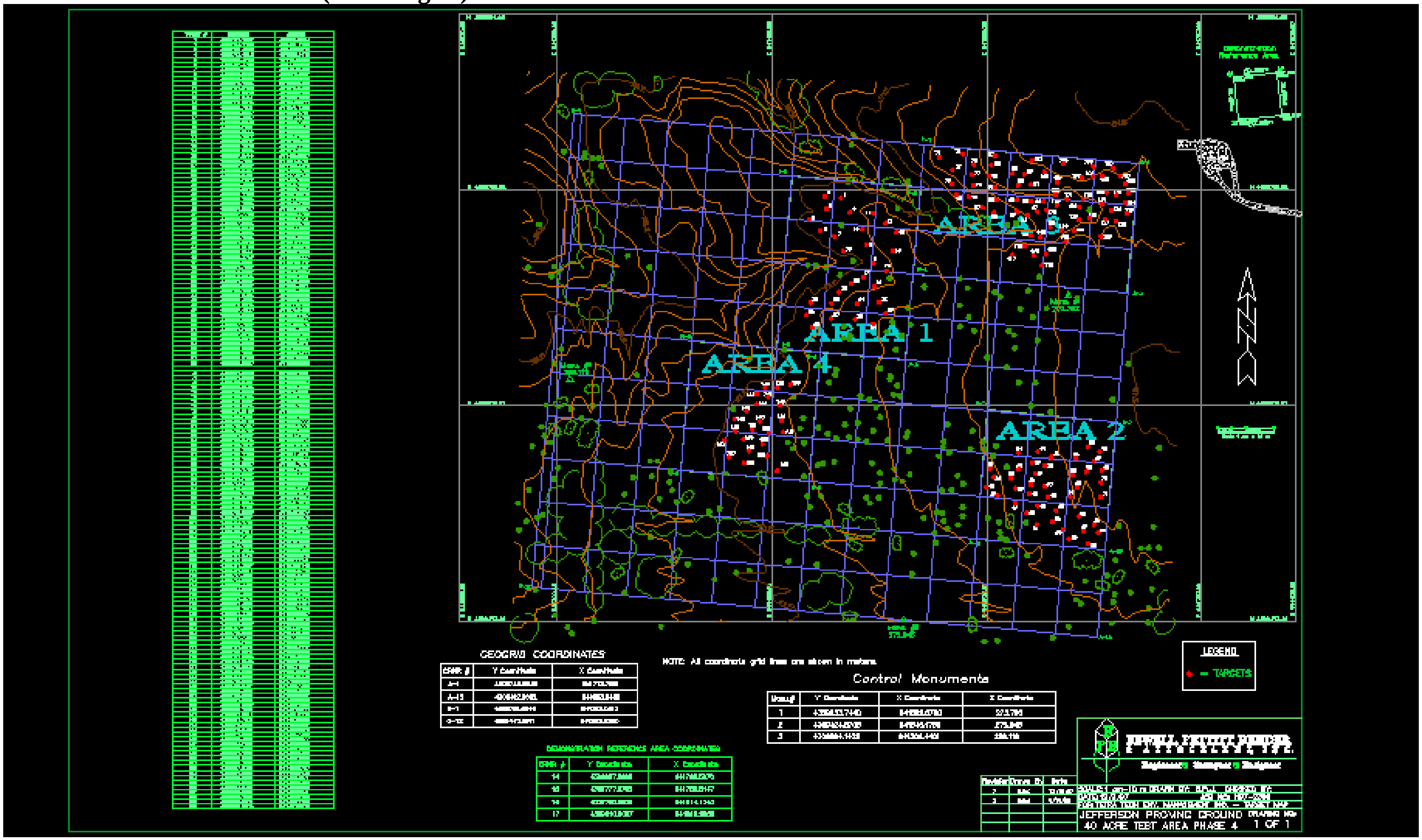
25 Targets missing from the Non-Ordnance Baseline

Concept Engineering Group

demonstrator	Scenario	target	northing	easting	Tetra Tech	Type	Travel Rate	Dig Time	Comments
					depth-m		k/hr	min.	
CEG	2	68	4309530.6987	641686.6266	0.367	152 mm proj.	16	34	
CEG	2	57	4309478.6079	641677.0733	0.632	4.2" mortar	16	14	
CEG	2	51	4309491.9892	641640.4295	1.498	57 mm proj.	16	120	
CEG	2	88	4309739.7898	641623.5044	0.254	76 mm HEAT	16	10	
CEG	2	89	4309739.3830	641631.7813	0.302	81 mm proj.	16	14	
CEG	2	99	4609719.9596	641645.3574	0.325	4.2" mortar	16	3	
CEG	2	118	4309681.4582	641638.2797	0.503	155 mm HEAT	16	9	
CEG	2	114	4309699.4430	641657.9399	1.133	105 mm proj.	16	180	
CEG	2	90	4309731.4799	641627.1256	0.785	152 mm proj.	16	5	
CEG	2	105	4309736.6163	641672.7084	1.680	152 mm proj.	16	130	
CEG	2	98	4309720.1761	641636.2995	0.589	57 mm proj.	16	25	
CEG	2	141	4309583.9011	641441.6773	0.484	90 mm AP	16	22	
CEG	2	11	4309711.9248	641524.5496	0.747	4.2" mortar	16	20	
CEG	2	145	4309571.6988	641434.7353	0.406	non ordnance	16	18	
CEG	2	100	4309724.7227	641654.0519	0.666	non ordnance	16	22	
CEG	2	24	4309633.6994	641524.6555	1.261	non ordnance	16	89	
CEG	2	25	4309647.9414	641494.9067	0.778	non ordnance	16	40	
CEG	2	28	4309648.3457	641480.0782	1.646	non ordnance	16	68	
CEG	2	92	4309721.1882	641626.8560	1.195	non ordnance	16	74	
CEG	2	135	4309725.5767	641705.7480	1.000	non ordnance	16	43	
CEG	2	134	4309719.0252	641703.2589	0.866	non ordnance	16	32	
CEG	2	41	4309525.6634	641610.2988	0.704	non ordnance	16	22	
CEG	2	36	4309531.0660	641627.8857	0.639	non ordnance	16	30	
CEG	2	122	4309699.0424	641666.6680	0.582	non ordnance	16	25	
CEG	2	109	4309737.3039	641680.2341	1.155	non ordnance	16	46	
CEG	2	106	4309744.7036	641680.6079	1.166	non ordnance	16	41	
CEG	2	128	4309706.0809	641696.8856	0.656	non ordnance	16	23	
CEG	2	136	4309732.4228	641703.4278	0.975	non ordnance	16	76	
CEG	2	140	4309588.1029	641447.8817	0.964	non ordnance	16	49	
CEG	2	160	4309533.9374	641457.3376	0.678	non ordnance	16	25	

APPENDIX B

JPG Phase IV – 40 Acre Site (with targets)



JPG Phase IV – 40 Acre Site (topographical)

JPG Phase IV Ground Truth – 16 Hectare (40-Acre Site)

TAR. #	SURVEY #	NORTHING	EASTING	DEPTH (m.)	TYPE	WEIGHT (Est)	SIZE	AZ. (Deg)	DEC. (Deg)	CLASS	DESCRIPTION	WEIGHT (Kg)	LENGTH (cm)	WIDTH (cm)	THICKNESS (cm)	DIAMETER (cm)
1	2764	4309722.7032	641501.6964	0.483	Nonordnance	Light	Small	-	-		Fragment (9.0)	4.1	22.9	15.2	7.6	-
2	2766	4309714.7198	641491.1256	0.456	Nonordnance	Light	Small	-	-		Fragment (13.5)	6.1	47.0	22.9	14.0	-
3	2768	4309723.4889	641489.9575	0.273	Ordnance	Light	Small	45	(-45) nose up	mortar	81 mm Mortar	4.1	45.7	-	-	8.1
4	2770	4309712.4513	641508.1419	0.295	Nonordnance	Light	Small	-	-		Fragment (4.5)	2.0	21.6	5.7	7.6	-
5	2772	4309699.3145	641487.2952	0.026	Ordnance	Light	Small	135	(+45) nose down	projectile	20 mm HE	0.1	7.6	-	-	2.0
6	2774	4309707.4780	641478.9258	0.114	Nonordnance	Light	Small	-	-		Fragment (0.3)	0.1	-	-	1.9	3.2
7	2776	4309695.3058	641497.2480	0.142	Nonordnance	Light	Small	-	-		Fragment (0.45)	0.2	12.7	-	-	1.9
8	2778	4309689.9635	641519.4151	0.797	Ordnance	Moderate	Medium	45	(-45) nose up	projectile	155 mm HE	43.2	71.1	-	-	15.5
9	2780	4309676.3815	641524.9589	0.776	Nonordnance	Moderate	Medium	-	-		Fragment (47.5)	21.6	42.6	-	-	12.7
10	2782	4309671.2855	641533.8465	1.772	Nonordnance	Moderate	Medium	-	-		Fragment (142.5)	64.8	66.0	30.5	16.5	-
11	2784	4309711.9248	641524.5496	0.747	Ordnance	Moderate	Medium	45	0	mortar	4.2 inch Mortar	10.0	53.3	-	-	10.7
12	3006	4309704.5973	641533.3263	0.386	Nonordnance	Light	Medium	-	-		Fragment (11.0)	5.0	23.0	14.0	2.5	-
13	2788	4309684.8441	641503.1903	0.105	Nonordnance	Light	Small	-	-		Fragment (0.15)	0.1	-	-	0.6	3.2
14	3008	4309700.0305	641516.8877	0.701	Nonordnance	Moderate	Small	-	-		Fragment (33.0)	15.0	33.0	26.0	6.5	-
15	2792	4309698.1601	641541.1325	0.728	Nonordnance	Moderate	Small	-	-		Fragment (22.0)	10.0	24.8	19.1	11.4	-
16	2794	4309685.3480	641538.4751	1.556	Nonordnance	Moderate	Medium	-	-		Fragment (95.0)	43.2	43.4	16.5	10.2	-
17	2796	4309666.4957	641517.3798	0.224	Ordnance	Light	Small	225	0	mortar	60 mm Mortar (w/o fuze)	1.5	30.5	-	-	6.0
18	2798	4309662.0578	641508.7390	0.339	Nonordnance	Light	Small	-	-		Fragment (3.2)	1.5	16.2	5.7	7.6	-
19	2800	4309660.1581	641525.2945	0.577	Nonordnance	Light	Small	-	-		Fragment (4.8)	2.2	22.2	5.7	7.6	-
20	2802	4309656.0144	641500.3560	0.476	Ordnance	Light	Small	225	0	projectile	57 mm (w/o fuze)	2.9	11.4	-	-	5.7
21	2804	4309647.7922	641513.1396	0.559	Ordnance	Light	Small	45	(-45) nose up	projectile	76 mm HE	6.8	45.1	-	-	7.6
22	2806	4309648.8579	641528.6493	0.711	Ordnance	Moderate	Medium	225	0	projectile	105 mm (w/o fuze)	15.0	36.8	-	-	10.5
23	2808	4309640.7573	641533.1100	0.551	Nonordnance	Light	Small	-	-		Fragment (16.5)	7.5	22.9	14.0	8.9	-
24	3010	4309633.6994	641524.6555	1.261	Nonordnance	Moderate	Medium	-	-		Fragment (49.5)	22.5	23.0	14.0	9.5	-
25	3012	4309647.9414	641494.9067	0.778	Nonordnance	Moderate	Small	-	-		Fragment (33.0)	15.0	30.0	26.0	6.5	-
26	2814	4309636.7391	641511.6791	0.256	Nonordnance	Light	Small	-	-		Fragment (1.6)	0.7	8.9	8.9	1.3	-
27	2816	4309637.3312	641494.3316	0.571	Ordnance	Moderate	Medium	45	(+45) nose down	projectile	152 mm	22.0	48.9	-	-	15.2
28	2818	4309648.3457	641480.0782	1.646	Nonordnance	Moderate	Medium	-	-		Fragment (48.5)	22.0	43.2	-	-	12.7
29	2820	4309639.5701	641477.0149	1.440	Nonordnance	Moderate	Medium	-	-		Fragment (72.75)	33.1	68.6	-	-	12.7
30	2822	4309631.1377	641481.1569	0.758	Nonordnance	Moderate	Small	-	-		Fragment (24.25)	11.0	63.5	7.6	7.6	-
31	3014	4309543.4536	641641.2868	0.326	Ordnance	Moderate	Small	135	(-45) nose up	projectile	90 mm AP	15.0	36.8	-	-	9.0
32	3016	4309539.5670	641651.1384	0.848	Nonordnance	Moderate	Medium	-	-		Fragment (49.5)	22.5	23.0	14.0	9.5	-

33	2686	4309536.1208	641637.0525	0.044	Ordnance	Light	Small	315	(-45) nose up	projectile	20 mm HE	0.1	7.6	-	-	2.0
34	2688	4309542.7559	641627.6585	0.065	Nonordnance	Light	Small	-	-		Fragment (0.15)	0.1	-	-	0.6	3.2
35	2690	4309533.2889	641646.4195	0.557	Nonordnance	Light	Small	-	-		Fragment (16.5)	7.5	22.9	14.0	8.9	-
36	3018	4309531.0660	641627.8857	0.639	Nonordnance	Moderate	Small	-	-		Fragment (33.0)	15.0	30.0	26.0	6.5	-
37	2694	4309527.7748	641639.3732	0.079	Nonordnance	Light	Small	-	-		Fragment (0.3)	0.1	-	-	1.9	3.2
38	2696	4309524.9229	641621.8741	0.107	Nonordnance	Light	Small	-	-		Fragment (0.45)	0.2	12.7	-	-	1.9
39	2698	4309517.6033	641625.2732	0.337	Ordnance	Light	Small	135	(+45) nose down	projectile	57 mm (w/o fuze)	2.9	11.4	-	-	5.7
40	2700	4309531.6078	641607.3828	0.214	Ordnance	Light	Small	135	(+45) nose down	mortar	60 mm Mortar (w/o fuze)	1.5	30.5	-	-	6.0
41	3020	4309525.6634	641610.2988	0.704	Nonordnance	Light	Small	-	-		Fragment (4.8)	2.2	23.0	14.0	2.5	-
42	3022	4309518.1664	641604.8853	0.365	Nonordnance	Light	Small	-	-		Fragment (3.2)	1.5	16.0	7.5	6.0	-
43	2706	4309512.9333	641612.7706	0.303	Nonordnance	Light	Small	-	-		Fragment (3.5)	1.6	8.9	8.9	3.8	-
44	2708	4309506.9198	641625.3579	0.429	Nonordnance	Light	Small	-	-		Fragment (9.45)	4.3	22.9	22.9	1.9	-
45	2710	4309513.3141	641635.2695	0.398	Nonordnance	Light	Small	-	-		Fragment (6.3)	2.9	31.1	5.7	7.6	-
46	2712	4309520.2743	641636.6327	0.172	Ordnance	Light	Small	225	0	projectile	76 mm HE	6.8	45.1	-	-	7.6
47	2714	4309518.9561	641646.0144	0.292	Ordnance	Light	Small	225	0	mortar	81 mm Mortar	4.1	45.7	-	-	8.1
48	2716	4309511.7342	641648.6154	0.547	Nonordnance	Light	Small	-	-		Fragment (15.0)	6.8	24.8	15.2	7.6	-
49	2718	4309505.2202	641641.0964	0.512	Nonordnance	Moderate	Small	-	-		Fragment (22.5)	10.2	24.8	15.2	7.6	-
50	2720	4309500.5075	641633.4921	0.574	Nonordnance	Light	Small	-	-		Fragment (7.5)	3.4	22.9	22.9	1.9	-
51	2722	4309491.9892	641640.4295	1.498	Ordnance	Moderate	Medium	315	(+45) nose down	projectile	152 mm	22.0	49.5	-	-	15.2
52	2724	4309493.9107	641651.4811	0.364	Ordnance	Moderate	Medium	135	(-45) nose up	projectile	105 mm	15.0	64.8	-	-	10.5
53	3024	4309502.1307	641654.4569	1.391	Nonordnance	Moderate	Medium	-	-		Fragment (72.75)	33.1	25.5	20.5	15.5	-
54	3026	4309488.6424	641658.9909	1.704	Nonordnance	Moderate	Medium	-	-		Fragment (48.5)	22.0	23.0	14.0	10.0	-
55	3028	4309481.4325	641663.2956	0.607	Nonordnance	Moderate	Small	-	-		Fragment (24.25)	11.0	23.0	14.0	4.5	-
56	2732	4309478.6079	641677.0733	0.999	Ordnance	Moderate	Medium	225	0	projectile	155 mm HE	43.2	71.1	-	-	15.5
57	2734	4309487.4870	641674.0428	0.632	Ordnance	Moderate	Medium	315	(+45) nose down	mortar	4.2 inch Mortar	10.0	53.3	-	-	10.7
58	2736	4309485.9556	641684.1457	0.835	Nonordnance	Moderate	Small	-	-		Fragment (22.0)	10.0	24.8	19.1	11.4	-
59	2738	4309492.0082	641680.9647	0.831	Nonordnance	Moderate	Small	-	-		Fragment (33.0)	15.0	61.0	20.3	5.1	-
60	3030	4309497.7949	641670.6678	0.602	Nonordnance	Light	Small	-	-		Fragment (11.0)	5.0	23.0	14.0	2.5	-
61	2742	4309511.1684	641664.3950	0.313	Ordnance	Light	Small	315	(+45) nose down	mortar	60 mm Mortar (w/o fuze)	1.5	30.5	-	-	6.0
62	2744	4309517.9778	641669.5160	0.163	Nonordnance	Light	Small	-	-		Fragment (1.6)	0.7	8.9	8.9	1.3	-
63	2746	4309526.9378	641666.1392	0.092	Ordnance	Light	Small	135	(-45) nose up	mortar	81 mm Mortar	4.1	45.7	-	-	8.1
64	2748	4309538.8893	641668.4821	0.322	Nonordnance	Light	Small	-	-		Fragment (9.0)	4.1	22.9	15.2	7.6	-
65	2750	4309547.0936	641676.5865	0.405	Nonordnance	Light	Small	-	-		Fragment (13.5)	6.1	47.0	22.9	14.0	-
66	3032	4309543.1691	641685.2422	0.601	Nonordnance	Light	Small	-	-		Fragment (4.5)	2.0	23.0	14.0	1.5	-
67	2754	4309537.0763	641680.9031	0.197	Ordnance	Light	Small	135	(-45) nose up	projectile	76 mm HE	6.8	49.5	-	-	7.6

68	2756	4309530.6987	641686.6266	0.367	Ordnance	Light	Small	315	(+45) nose down	projectile	57 mm (w/o fuze)	2.9	11.4	-	-	5.7
69	3034	4309529.6511	641675.5922	0.558	Nonordnance	Light	Small	-	-		Fragment (6.3)	2.9	23.0	14.0	1.5	-
70	2760	4309521.6268	641686.1291	0.491	Nonordnance	Light	Small	-	-		Fragment (9.45)	4.3	22.9	22.9	1.9	-
71	2762	4309511.2566	641685.8505	0.370	Nonordnance	Light	Small	-	-		Fragment (3.5)	1.6	8.9	8.9	3.8	-
72	2824	4309741.8481	641580.8004	0.051	Ordnance	Light	Small	45	0	projectile	20 mm HE	0.1	7.6	-	-	2.0
73	2826	4309732.6124	641580.4389	0.105	Nonordnance	Light	Small	-	-		Fragment (0.3)	0.1	-	-	1.9	3.2
74	2828	4309750.9106	641571.3801	0.217	Nonordnance	Light	Small	-	-		Fragment (0.45)	0.2	12.7	-	-	1.9
75	2830	4309753.5295	641588.1663	0.133	Nonordnance	Light	Small	-	-		Fragment (0.15)	0.1	-	-	0.6	3.2
76	2832	4309745.9382	641596.0905	0.525	Nonordnance	Light	Small	-	-		Fragment (16.5)	7.5	22.9	14.0	8.9	-
77	3036	4309738.5574	641594.2038	0.688	Nonordnance	Moderate	Small	-	-		Fragment (33.0)	15.0	23.0	14.0	5.5	-
78	3038	4309731.3193	641596.0086	0.938	Nonordnance	Moderate	Medium	-	-		Fragment (49.5)	22.5	23.0	14.0	9.5	-
79	3040	4309723.1531	641592.1086	0.530	Ordnance	Moderate	Small	315	(-45) nose up	projectile	90 mm AP	15.0	36.8	-	-	9.0
80	2840	4309724.9196	641583.6774	0.314	Ordnance	Light	Small	45	0	projectile	57 mm (w/o fuze)	2.9	11.4	-	-	5.7
81	2842	4309715.7457	641601.8770	0.286	Ordnance	Light	Small	45	0	mortar	60 mm Mortar (w/o fuze)	1.5	22.9	-	-	6.0
82	2844	4309712.3792	641610.3568	0.407	Nonordnance	Light	Small	-	-		Fragment (9.45)	4.3	22.9	22.9	1.9	-
83	3042	4309721.0529	641611.7808	0.417	Nonordnance	Light	Small	-	-		Fragment (3.5)	1.6	8.9	8.9	3.8	-
84	3044	4309730.0474	641610.9674	0.583	Nonordnance	Light	Small	-	-		Fragment (4.8)	2.2	23.0	14.0	2.5	-
85	3046	4309737.7579	641607.0157	0.383	Nonordnance	Light	Small	-	-		Fragment (6.3)	2.9	23.0	14.0	1.5	-
86	2852	4309745.2530	641608.3113	0.291	Nonordnance	Light	Small	-	-		Fragment (1.6)	0.7	8.9	8.9	1.3	-
87	3048	4309752.1200	641611.4021	0.354	Nonordnance	Light	Small	-	-		Fragment (3.2)	1.5	16.0	7.5	6.0	-
88	2856	4309739.7898	641623.5044	0.254	Ordnance	Light	Small	315	(-45) nose up	projectile	76 mm HE	6.8	49.5	-	-	7.6
89	2858	4309739.3830	641631.7813	0.302	Ordnance	Light	Small	315	(-45) nose up	mortar	81 mm Mortar (w/o fuze)	3.7	43.2	-	-	8.1
90	2860	4309731.4799	641627.1256	0.785	Ordnance	Moderate	Medium	135	(+45) nose down	projectile	155 mm HE (w/ lifting lug)	43.2	67.3	-	-	15.5
91	3050	4309731.8802	641636.3398	0.719	Nonordnance	Moderate	Medium	-	-		Fragment (47.5)	21.6	42.0	21.0	6.5	-
92	2864	4309721.1882	641626.8560	1.195	Ordnance	Moderate	Medium	135	(+45) nose down	projectile	152 mm	22.0	49.5	-	-	15.2
93	3052	4309713.1336	641626.8921	1.506	Nonordnance	Moderate	Medium	-	-		Fragment (95.0)	43.2	23.0	19.0	14.0	-
94	3054	4309710.0658	641634.0774	1.451	Nonordnance	Moderate	Medium	-	-		Fragment (72.75)	33.1	25.5	20.5	15.5	-
95	3056	4309696.2846	641636.2818	0.655	Nonordnance	Moderate	Small	-	-		Fragment (24.25)	11.0	23.0	14.0	4.5	-
96	2872	4309701.6451	641650.2054	1.636	Nonordnance	Moderate	Medium	-	-		Fragment (142.5)	64.8	66.0	30.5	16.5	-
97	3058	4309713.0544	641641.1070	1.685	Nonordnance	Moderate	Medium	-	-		Fragment (48.5)	22.0	23.0	14.0	10.0	-
98	2876	4309720.1761	641636.2995	0.589	Ordnance	Moderate	Medium	315	(-45) nose up	projectile	105 mm	15.0	64.8	-	-	10.5
99	2878	4309719.9596	641645.3574	0.325	Ordnance	Moderate	Medium	135	(+45) nose down	mortar	4.2 inch Mortar	10.0	53.3	-	-	10.7
100	3060	4309724.7227	641654.0519	0.666	Nonordnance	Moderate	Small	-	-		Fragment (33.0)	15.0	23.0	14.0	5.5	-
101	2882	4309733.4743	641655.2261	0.487	Nonordnance	Light	Small	-	-		Fragment (16.5)	7.5	22.9	14.0	8.9	-
102	3062	4309740.6605	641646.0157	0.405	Nonordnance	Light	Small	-	-		Fragment (11.0)	5.0	23.0	14.0	2.5	-

103	2886	4309749.1911	641637.0112	0.799	Nonordnance	Moderate	Small	-	-		Fragment (33.0)	15.0	61.0	20.3	5.1	-
104	2888	4309746.1455	641659.9074	0.511	Ordnance	Moderate	Small	45	0	projectile	90 mm AP	15.0	36.8	-	-	9.0
105	2894	4309736.6163	641672.7084	1.680	Ordnance	Moderate	Medium	225	0	projectile	152 mm	22.0	49.5	-	-	15.2
106	3064	4309744.7036	641680.6079	1.166	Nonordnance	Moderate	Medium	-	-		Fragment (72.75)	33.1	25.5	20.5	15.5	-
107	3066	4309743.4314	641695.0465	1.363	Nonordnance	Moderate	Medium	-	-		Fragment (48.5)	22.0	23.0	14.0	10.0	-
108	2900	4309737.9479	641686.8510	0.786	Ordnance	Moderate	Medium	315	(+45) nose down	projectile	155 mm HE	43.2	71.1	-	-	15.5
109	3068	4309737.3039	641680.2341	1.155	Nonordnance	Moderate	Medium	-	-		Fragment (95.0)	43.2	23.0	19.0	14.0	-
110	3070	4309721.7257	641673.2145	0.834	Nonordnance	Moderate	Medium	-	-		Fragment (47.5)	21.6	42.0	21.0	6.5	-
111	3072	4309721.8511	641661.9743	0.817	Nonordnance	Moderate	Small	-	-		Fragment (24.25)	11.0	23.0	14.0	4.5	-
112	2908	4309717.4803	641654.6360	1.863	Nonordnance	Moderate	Medium	-	-		Fragment (142.5)	64.8	66.0	30.5	16.5	-
113	2910	4309713.8929	641647.6050	0.112	Ordnance	Light	Small	225	0	projectile	20 mm HE	0.1	7.6	-	-	2.0
114	2912	4309699.4430	641657.9399	1.133	Ordnance	Moderate	Medium	45	(+45) nose down	projectile	152 mm	22.0	49.5	-	-	15.2
115	2914	4309694.8690	641643.2166	0.069	Nonordnance	Light	Small	-	-		Fragment (0.3)	0.1	-	-	1.9	3.2
116	2916	4309688.4696	641631.8135	0.047	Nonordnance	Light	Small	-	-		Fragment (0.15)	0.1	-	-	0.6	3.2
117	2918	4309682.4102	641623.2747	0.680	Ordnance	Moderate	Medium	45	0	projectile	155 mm HE	43.2	71.1	-	-	15.5
118	2920	4309681.4582	641638.2797	0.503	Ordnance	Light	Small	45	(+45) nose down	projectile	57 mm (w/o fuze)	2.9	11.4	-	-	5.7
119	3074	4309674.7221	641644.1734	0.675	Nonordnance	Light	Small	-	-		Fragment (6.3)	2.9	23.0	14.0	1.5	-
120	2924	4309683.2732	641646.8557	0.500	Nonordnance	Light	Small	-	-		Fragment (15.0)	6.8	24.8	15.2	7.6	-
121	2926	4309691.6496	641660.9546	0.627	Nonordnance	Light	Small	-	-		Fragment (7.5)	3.4	22.9	22.9	1.9	-
122	2928	4309699.0424	641666.6680	0.587	Nonordnance	Moderate	Small	-	-		Fragment (22.5)	10.2	24.8	15.2	7.6	-
123	2930	4309707.4266	641670.5189	0.315	Ordnance	Light	Small	45	0	projectile	76 mm HE	6.8	49.5	-	-	7.6
124	2932	4309716.3620	641670.8394	0.549	Ordnance	Light	Small	45	0	mortar	81 mm Mortar	4.1	45.7	-	-	8.1
125	2934	4309707.7725	641677.9689	0.340	Nonordnance	Light	Small	-	-		Fragment (9.0)	4.1	22.9	15.2	7.6	-
126	2936	4309695.1010	641686.2686	0.443	Nonordnance	Light	Small	-	-		Fragment (13.5)	6.1	47.0	22.9	14.0	-
127	3076	4309707.3951	641689.4222	0.631	Nonordnance	Light	Small	-	-		Fragment (4.5)	2.0	23.0	14.0	1.5	-
128	3078	4309706.0809	641696.8856	0.656	Nonordnance	Light	Small	-	-		Fragment (4.5)	2.0	23.0	14.0	1.5	-
129	2942	4309711.3264	641704.3392	0.357	Nonordnance	Light	Small	-	-		Fragment (9.0)	4.1	22.9	15.2	7.6	-
130	2944	4309713.8164	641693.2683	0.491	Nonordnance	Light	Small	-	-		Fragment (13.5)	6.1	47.0	22.9	14.0	-
131	2946	4309718.2679	641687.1084	0.538	Nonordnance	Light	Small	-	-		Fragment (15.0)	6.8	24.8	15.2	7.6	-
132	2948	4309726.2612	641690.0878	0.617	Ordnance	Moderate	Medium	225	0	mortar	4.2 inch Mortar	10.0	49.5	-	-	10.7
133	2950	4309724.2303	641697.0443	0.492	Nonordnance	Moderate	Small	-	-		Fragment (22.0)	10.0	24.6	19.1	11.4	-
134	2952	4309719.0252	641703.2589	0.866	Nonordnance	Moderate	Small	-	-		Fragment (33.0)	15.0	61.0	20.3	5.1	-
135	3080	4309725.5767	641705.7480	1.000	Nonordnance	Moderate	Medium	-	-		Fragment (49.5)	22.5	23.0	14.0	9.5	-
136	3082	4309732.4228	641703.4278	0.975	Nonordnance	Moderate	Small	-	-		Fragment (33.0)	15.0	23.0	14.0	5.5	-
137	2958	4309738.0695	641699.6002	0.619	Ordnance	Moderate	Medium	45	0	projectile	105 mm	15.0	54.6	-	-	10.5
138	2960	4309591.0823	641465.6350	0.543	Ordnance	Moderate	Small	225	0	projectile	90 mm AP	15.0	36.8	-	-	9.0

139	2962	4309588.3687	641456.7064	0.820	Nonordnance	Moderate	Small	-	-		Fragment (33.0)	15.0	61.0	20.3	5.1	-
140	2964	4309588.1029	641447.8817	0.964	Nonordnance	Moderate	Medium	-	-		Fragment (49.5)	22.5	42.6	-	-	12.7
141	2966	4309583.9011	641441.6773	0.484	Ordnance	Moderate	Small	45	(+45) nose down	projectile	90 mm AP	15.0	36.8	-	-	9.0
142	2968	4309581.7806	641450.0555	0.506	Nonordnance	Light	Small	-	-		Fragment (16.5)	7.5	22.9	14.0	8.9	-
143	2970	4309575.8831	641458.8054	0.702	Nonordnance	Moderate	Small	-	-		Fragment (33.0)	15.0	61.0	20.3	5.1	-
144	2972	4309576.9436	641442.0210	0.271	Nonordnance	Light	Small	-	-		Fragment (1.6)	0.7	8.9	8.9	1.3	-
145	2974	4309571.6988	641434.7353	0.406	Nonordnance	Light	Small	-	-		Fragment (3.2)	1.5	16.2	5.7	7.6	-
146	2976	4309566.4851	641426.0077	0.524	Ordnance	Light	Small	45	(+45) nose down	mortar	60 mm Mortar	1.5	15.2	-	-	6.0
147	2978	4309564.7999	641443.9335	0.451	Nonordnance	Light	Small	-	-		Fragment (4.8)	2.2	22.2	5.7	7.6	-
148	2980	4309565.4019	641459.2680	0.488	Ordnance	Moderate	Medium	45	(+45) nose down	projectile	105 mm	15.0	64.8	-	-	10.5
149	2982	4309557.2323	641460.6456	0.692	Nonordnance	Moderate	Medium	-	-		Fragment (49.5)	22.5	42.6	-	-	12.7
150	2984	4309556.9346	641450.1952	0.724	Nonordnance	Moderate	Small	-	-		Fragment (33.0)	15.0	61.0	20.3	5.1	-
151	2986	4309559.1890	641438.9692	0.560	Nonordnance	Light	Small	-	-		Fragment (16.5)	7.5	22.9	15.2	8.9	-
152	2988	4309557.9795	641426.6787	0.553	Ordnance	Moderate	Medium	45	(+45) nose down	mortar	4.2 inch Mortar (w/o fuze)	10.0	50.8	-	-	10.7
153	2990	4309551.5495	641418.8173	0.383	Nonordnance	Moderate	Small	-	-		Fragment (22.0)	10.0	24.8	19.1	11.4	-
154	2992	4309552.5653	641432.4971	0.474	Nonordnance	Light	Small	-	-		Fragment (11.0)	5.0	33.0	-	-	10.2
155	2994	4309548.9508	641445.8415	0.044	Ordnance	Light	Small	45	0	projectile	20 mm HE	0.1	7.6	-	-	2.0
156	2996	4309543.9401	641436.5504	0.134	Nonordnance	Light	Small	-	-		Fragment (0.3)	0.1	-	-	1.9	3.2
157	2998	4309539.5701	641422.2841	0.134	Nonordnance	Light	Small	-	-		Fragment (0.45)	0.2	12.7	-	-	1.9
158	3000	4309535.2390	641432.6788	0.111	Nonordnance	Light	Small	-	-		Fragment (0.15)	0.1	-	-	0.6	3.2
159	3002	4309540.5800	641449.2209	0.185	Nonordnance	Light	Small	-	-		Fragment (0.45)	0.2	12.7	-	-	1.9
160	3004	4309533.9374	641457.3376	0.678	Nonordnance	Moderate	Small	-	-		Fragment (33.0)	15.0	61.0	20.3	5.1	-

B-1 QUALITY ASSURANCE

B-1.1 Horizontal and Vertical Position Error for Ordnance Targets

All ordnance and non-ordnance targets for JPG Phase IV were surveyed in the ground by a commercial surveying company (Fewell, Petite, and Bender). All ordnance that was placed in the ground with its rotational axis parallel to the earth's horizontal plane was measured from the top center of the ordnance case to the ground surface. Ordnance that was buried at an angle with the horizontal plane was measured from the nose to the ground surface (in the case of a nose upward orientation) and from the tail to the ground surface (in the case of a nose down orientation). The excavation was filled in and a flag placed directly over the ordnance item (the flag was surveyed as well). In addition, a wooden hub was placed approximately one (1) foot west of surface locations to facilitate re-positioning of flags after periodic grass cutting.

During the demonstrations, if a vendor had any question about target locations, the targets' flag in question was measured with respect to other target flags in the general vicinity. Following any removal of flags or grass cutting operations, a spot check of approximately half the targets was conducted. This was done two times in the period August 1998 to October 1998 (results not included in final report).

After the discrimination demonstrators finished a further QC of the area was performed by CEG and the surveyors. CEG's method of uncovering ordnance was a good opportunity to double-check the original site layout. When CEG uncovered a target the surveyor would record the location. In addition, many small ordnance and non-ordnance targets were uncovered by hand and resurveyed. The following table (D-1) shows the result of this operation.

Table B-1:

Average Radial Error in Horizontal Plane (42 targets/half hand-dug)	Standard Deviation in Horizontal Plane (42 targets/half hand-dug)	Average Depth Error (for 41 targets/half hand-dug – negative # indicates shallower over time)	Standard Deviation for Depth (for 41 targets/half hand-dug)
5 cm	**4.5 cm**	**-2.9 cm**	**6.5 cm**

B-1.2 Orientation Error for Ordnance Targets

Burial orientation was recorded for all ordnance targets. This included the azimuth direction (direction of the nose with respect to the horizontal plane) measured from 0^o (north) to 359^o in a clockwise manner and the declination direction (measurement of the angle of tilt from the nose to the horizontal plane) which included $+90^o$ (nose down) to $+90^o$ (nose up). The following table D-2 shows the results of this operation

Table B-2:

Average Azimuth Error in Horizontal Plane (12 targets/half hand-dug)	Standard Deviation in Horizontal Plane (12 targets/half hand-dug)	Average Declination Error (11 targets/half hand-dug	Standard Deviation for Declination (11 targets/half hand-dug)
29^o	**23^o**	**16^o**	**18^o**

From the above table it was determined that no meaningful statistics could be drawn from the demonstrator data due to errors in the ground truth data.

B-1.3 Aspect Ratios of Ordnance and Non-Ordnance Targets

Aspect ratios can be a problem to some types of sensors that rely on length to width ratios (aspect) as a discrimination parameter. This is especially true for high-resolution sensors such as ground penetrating radar (GPR).

Aspect ratios of ordnance buried at JPG averaged 4.5 with a standard deviation of 1.4. Since all ordnance targets buried at JPG were either projectiles or mortars, the aspect ratios were relatively uniform.

Aspect ratios of non-ordnance targets were more diverse. Of the 110 non-ordnance targets emplaced, 89 were "plate like", 11 were "ordnance like", and 10 were "coin like". The breakdown of aspect ratios and standard deviations are in the following table.

Table B-3

"Plate Like" Non-Ordnance Targets (89 items)		"Ordnance Like" Non-Ordnance Targets (11 items)		"Coin Like" Non-Ordnance Targets (10 items)	
Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
1.9	**1.0**	**5.0**	**1.7**	**NA**	**NA**

Table B-4 and following pictures show the area breakdown of these "ordnance looking" non-ordnance targets.

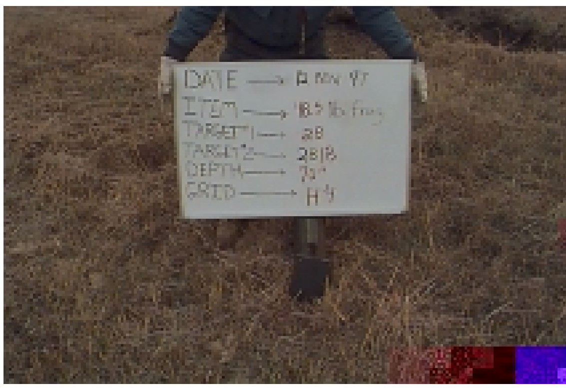
Table B-4

Area	Target Numbers
1	7,9,28,29
2	38
3	74
4	140,149,154,157,159

AREA 1


DATE → 12 NOV 97
ITEM → .45 lb. frag
TARGET#1 → 7
TARGET#2 → 2776
DEPTH → 8"
GRID → G-3


TARGET#1 →
TARGET#2 → 2780
DEPTH → 40"
GRID → F-3


DATE → 12 NOV 97
ITEM → 18.5 lb. frag
TARGET#1 → 28
TARGET#2 → 2818
DEPTH →
GRID →


DATE → 12 NOV 97
ITEM →
TARGET#1 →
TARGET#2 →
DEPTH →
GRID →

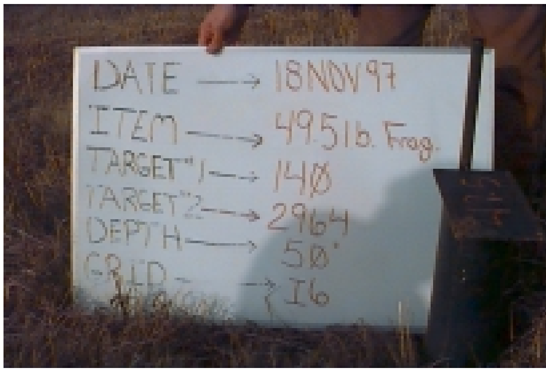
AREA 2

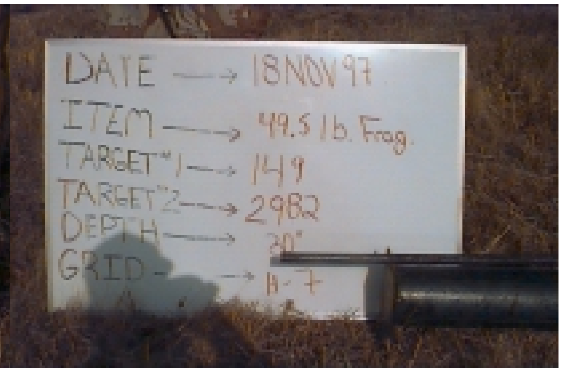

DATE → 11-11-97
ITEM → .45 lb frag
TARGET #1 → #38
TARGET #2 → #2696
DEPTH → 8"
GRID → C-8

AREA 3

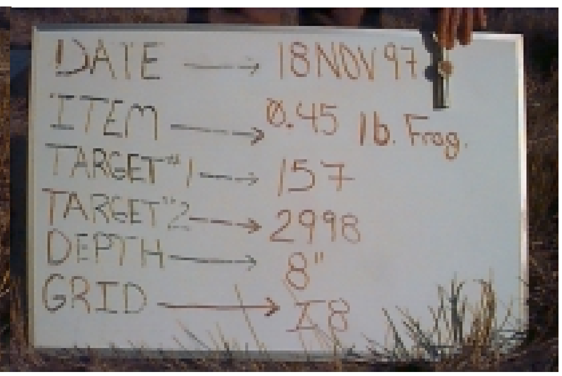

DATE → 12 NOV 97
ITEM → .45 lb frag
TARGET #1 → 74
TARGET #2 → 2828
DEPTH → 8"
GRID → E1

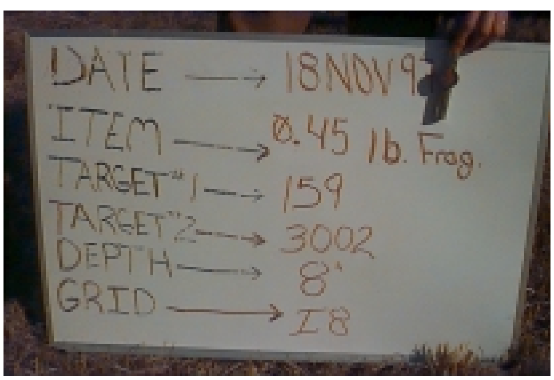
AREA 4


DATE → 18NOV97
ITEM → 49.5 lb. Frag.
TARGET#1 → 14Ø
TARGET#2 → 2964
DEPTH → 5Ø"
GRID → I6


DATE → 18NOV97
ITEM → 49.5 lb. Frag.
TARGET#1 → 149
TARGET#2 → 2982
DEPTH → 30"
GRID


DATE → 18NOV97
ITEM → 11.Ø lb. Frag.
TARGET#1 → 154
TARGET#2 → 2992
DEPTH → 26"
GRID → I8


DATE → 18NOV97
ITEM → Ø.45 lb. Frag.
TARGET#1 → 157
TARGET#2 → 2998
DEPTH → 8"
GRID → I8


DATE → 18NOV97
ITEM → Ø.45 lb. Frag.
TARGET#1 → 159
TARGET#2 → 3002
DEPTH → 8"
GRID → I8

A table of "ordnance like" non-ordnance and the number of correctly discriminated demonstrator declarations is included as background information.

Table B-5

Target Number	Number of Demonstrators that Correctly Discriminated this Target (10 Total Discrimination Demonstrators)
7	5
9	6
28	5
29	5
38	8
74	6
140	2
149	5
154	1
157	6
159	5

Note: From the pictures on the previous page, targets #140 and #149 are physically identical. However, #140 was buried at .964 meters and #149 at .692 meters, orientation unknown. Target #154 was buried at .474 meters

B-1.4 SITE OPERATIONS AND PROCEDURES

Shortly after the completion of Phase II demonstrations, JPG became an inactive facility. As a result, most JPG personnel have been relocated, and they were not able to provide support services for Phase IV demonstrations. However, remaining JPG personnel offered to provide contact names and telephone numbers for mowing service companies, earthmovers, and other necessary services. The following subsections discuss site security, safety procedures, and points of contact.

B-1.4.1 Site Security

According to Mr. Ken Knouf, site manager, the main gate entrance located on Indiana Highway 421 were maintained by security personnel at all times. An additional locked gate was installed at the firing line, limiting access to the 16- and 32-hectare areas. Tetra Tech used this entrance and the Gate 5 entrance during the course of Phase IV demonstrations. Tetra Tech had a key for both gates. JPG had no active security force, and site security was shared between remaining JPG personnel and local law enforcement. JPG personnel informed Tetra Tech that local law enforcement did not routinely patrol the base. Also, trespassing occurred frequently on the north side of the base, and continued to be a concern throughout the demonstrations. The field trailers, installed in spring 1998, were secured at all times. In addition, Tetra Tech has access to

Building 444, located about 0.5 mile south of the 16-hectare area, for storage during Phase IV ordnance emplacement activities.

B-1.4.2 Safety Procedures

During validation activities in October 1995, live ordnance was discovered on the south end of the 32-hectare site. Because the possibility existed that live ordnance could be encountered during Phase IV emplacement activities, all activities were performed in a safe and responsible manner. All field activities were completed in accordance with the Safety, Health, and Emergency Response Plan (SHERP) developed in accordance with the demonstration work plan. Tetra Tech personnel were responsible for the implementation of the SHERP, and ensured that all contractors involved with Phase IV activities were in compliance with the SHERP. Anyone violating the SHERP was subject to removal from the site.

APPENDIX C

Battelle/Ohio State University ElectroScience Laboratory
JPG IV Survey Data Analysis Report

1 Introduction

This report describes the Battelle/ESL Unexploded Ordnance (UXO) characterization system demonstrated at the Jefferson Proving Ground 40 acre site from September 21 to 25, 1998.

1.1 Company Descriptions

Battelle, 505 King Ave., Columbus, OH 43201
Project Manager: Jennifer Halman, (614) 424-7791

The Ohio State University, ElectroScience Laboratory (ESL), 1320 Kinnear Road, Columbus, OH 43212
Project Manager: Dr. Jonathan Young, (614) 292-6657

1.2 Project Team and Roles

Battelle managed the overall program, designed and built the platform for the GPR antenna, and assisted during the demonstration. ESL, a subcontractor to Battelle, designed, developed, and built the radar and the controlling system. ESL also operated the system during the demonstration and analyzed the resulting data.

2 Demonstrated Technologies

2.1 Sensor System and Transport Mode

The Battelle/ESL UXO characterization system is a manually-operated, surface-towed, ground penetration radar (GPR). Because the target locations were marked with flags, we did not use any navigation system other than a compass and the site map. The radar is a Hewlett Packard Network Analyzer (HP8753C), which measures multiple frequency responses by sweeping the frequency from 20 MHz to 420 MHz in 2-MHz steps. We chose this frequency range to match most UXOs' resonance frequencies and achieve maximum ground penetration. The 400 MHz bandwidth also provides 2.5-nanosecond (ns) depth resolution (approximately 7 inches in dry sand and 3 to 5 inches in clay). We used a laptop computer to control the network analyzer and collect the data. We mounted the computer and network analyzer on an all-terrain vehicle (ATV), which we also used to tow the specially designed GPR antenna.

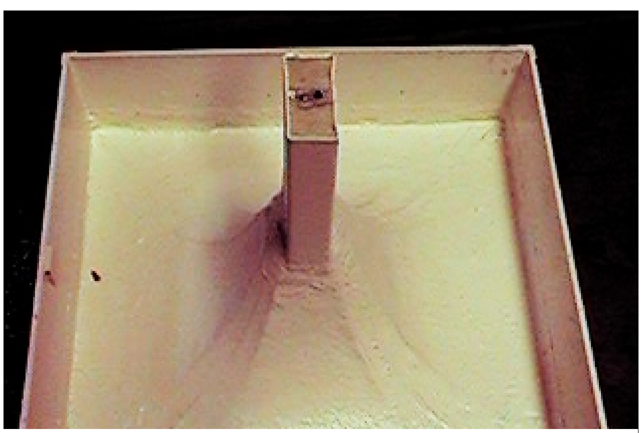


Figure 1 The New ESL Dual-Polarization GPR Antenna Filled with Low Loss Dielectric Material

The GPR antenna is a dual-polarized dielectric-loaded, horn-fed bow tie (HFB) antenna, as shown in Figure 1. Such HFB antennas are much more stable and sensitive when the dielectric constant of the material filling the antenna volume is approximately equal to the dielectric constant of the ground under test. The custom designed antenna is actually two HFB antennas combined and oriented along the diagonals to minimize mutual coupling. Although the preferred operational mode is to transmit the radar signal from one antenna and receive from the other one, i.e., cross-polarized mode, we can also obtain co-polarized data by transmitting and receiving from the same antenna. The rotational feature of Battelle/ESL GPR helps discriminate linear

targets, such as UXO, from non-linear targets. It also provides some orientation information about the target's axis. Unfortunately, the co-polarized data were corrupted and could not be used for data processing during the demonstration. The goals of the Battelle/ESL GPR system is to provide shape (linearity), depth, length, and azimuthal orientation information to assist the UXO classification.

2.2 Recommended Applications and Technology Limitations

Classification of targets with the Battelle/ESL GPR, combined with detection of targets using magnetic sensors, could provide a good tool for UXO clearance. By providing additional feature information, such as shape, length, depth, and azimuthal orientation, the Battelle/ESL GPR can identify and eliminate many false alarms. The system's performance is limited by scattering due to the natural ground inhomogeneity and by surface roughness. The depressions at the JPG target sites created large air gaps, due to settling after target burial, between the antenna and the ground. This situation resulted in non-optimal antenna performance as well as errors in the feature estimation of shallow targets. The maximum penetration depth is limited by the soil conductivity, which is usually a strong function of moisture content. Wet soil absorbs more energy and thus reduces the radar penetration depth.

2.3 Logistics and Data Acquisition

For each target measurement, we towed the antenna to a target site with the ATV and lowered the antenna onto the ground surface. We rotated the antenna a total of 180 degrees, in 10-degree steps. At each angle, the co-polarized and cross-polarized field data were measured at multiple frequencies. The average time for measuring one target was approximately 7 minutes, including driving from target to target.

2.4 Data Processing and Interpretation

2.4.1 Depth Estimation

To estimate the depth of the target, we first transformed the frequency-domain data into time domain data using the Fast Fourier Transformation (FFT). Figure 2 shows the time-domain amplitude plot plotted as a function of polarization angle. The vertical scale indicates the negative of the delay time of the return signal. The earliest strong return, located at about -17 ns, is the surface roughness. Two strong spots separated by approximately 90 degrees indicate that the surface roughness is not rotationally symmetric and has a highly linear shape. The two strong signal returns arriving approximately 5 ns later than the surface reveal the depth of the buried object. The target in Figure 2 is located at a depth of 8 inches, given a permittivity of 14 as was measured with the ESL soil probe.

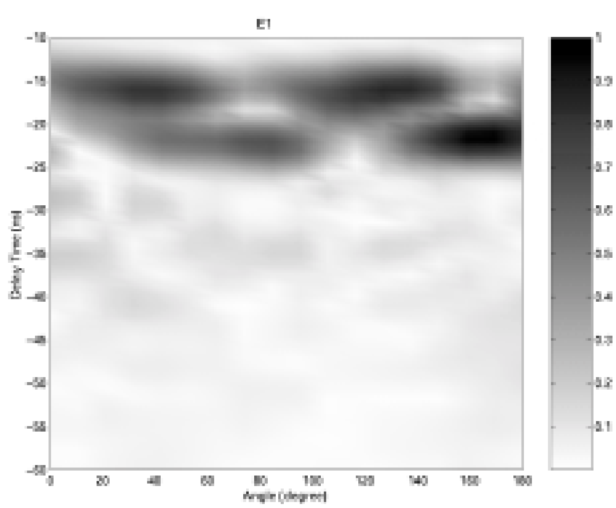


Figure 2 The Time-Angle Plot of the Amplitude of the Cross-Polarized Data for Target #1 of the 10 "Extra" Targets

2.4.2 Shape Linearity Estimation

The elongated body feature of a UXO target is an important classifier for discriminating most UXO from clutter. By measuring the response of a target with a rotating, cross-polarized or co-polarized antenna, one can determine whether the

target has an elongated body (or linear shape). This discrimination is achieved by transforming the angular response into its angular spectrum using a simple FFT, as demonstrated in Figures 3 and 4 for co-polar data. In the angular spectrum domain (right hand side), a linear target would give a response located at $1/\pi$ angular frequency as shown in Figure 3. A rotationally invariant target would only give a response at 0 angular frequency. Such an angular transformation can also be applied to our time-angle cross-polarized UXO data, as shown in Figures 5 and 6. The rough, irregularly shaped surface creates a high angular frequency response in the early time region. The behavior of the late time region is primarily determined by the buried object. The target in Figure 5 shows a high angular frequency response in the late time region and thus does not have the elongated body of a typical UXO. This type of target is classified a non-UXO target. Figure 6 shows a high energy concentration at $1/\pi$ angular frequency in the late time region and is thus classified as an UXO target. This is the criterion that we used to discriminate UXO targets from clutter in our results.

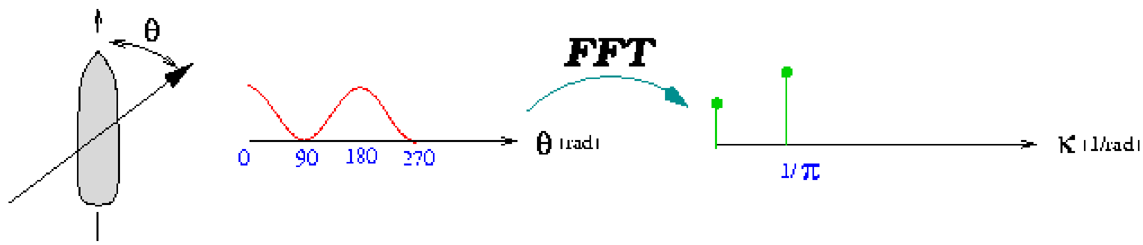


Figure 3 The Angular Spectrum of the Co-Polarized Data for a Linear Target

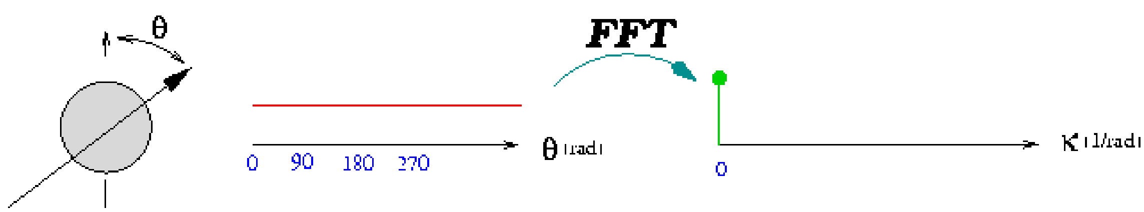


Figure 4 The Angular Spectrum of the Co-Polarized Data for a Rotational Symmetric Target

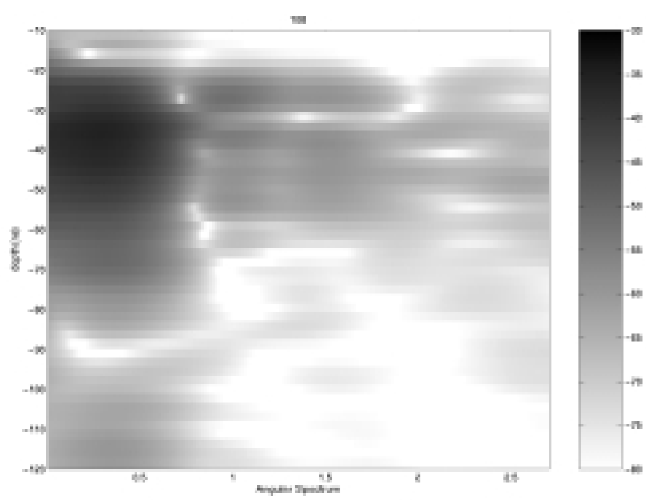


Figure 5 The Time-Angular Spectrum of a Non-UXO Class of Target

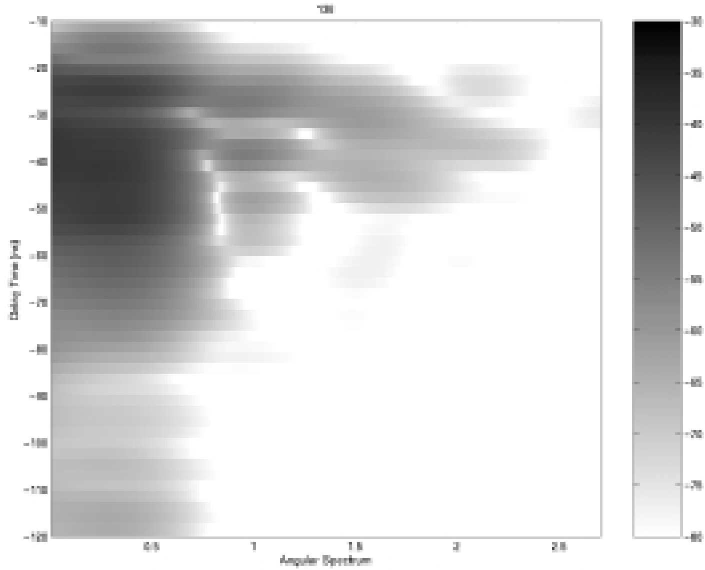


Figure 6 The Time-Angular Spectrum of a UXO Class of Target

2.4.3 Length Estimation

For each selected UXO target, its length is estimated using the free-space half-resonance length that was obtained from the natural resonance frequency extracted from the measured data and the knowledge of the permittivity[1]. We did not calculate the length of the non-ordnance targets.

2.4.4 Orientation Estimation

For each selected UXO target, we estimated the orientation of the axis from the angle positions of peak responses as shown in Figure 2. We cannot distinguish the tip from the tail of the UXO with the current process, which results in a 180-degree ambiguity. Due to the contamination of the co-polarization data obtained during this demonstration, the target azimuth orientation has an additional 90-degree ambiguity. For example, the processing cannot distinguish between orientations of 0 degrees, 90 degrees, 180 degrees, and 270 degrees. In the future, if good co-polarization data is combined with cross-polarization data, the additional 90-degree ambiguity can be eliminated.

3 Demonstration Results

3.1 Site-Specific Procedures

The measurement procedure was to follow a path through all of the targets that minimized the movement of the electrical power generator. We assumed that the flags accurately marked the target locations. We used the ATV to tow the antenna platform to each target location. Then we lowered the antenna platform to the ground surface and performed the radar measurement. After the measurement, we elevated the antenna platform for transportation. At the end of each day, we performed system calibration measurements using standard loads and a long conducting wire.

3.2 Problems Encountered

The automated rotational mechanism for the antenna failed to function properly over the rough terrain so we rotated the antenna manually for the remainder of the demonstration. We performed one on-site

repair to fix the two signal cables that were broken accidentally. The co-polarized antenna data were contaminated due to a hardware problem, so only the cross-polarized antenna data were used for this analysis.

3.3 Raw Data

The raw radar data sets are included on the attached ZIP cartridge. There is one header file (*.hdr) and one data file (*.dat) for each day that we collected data. The files are all ASCII files that can be viewed with a program such as *Notepad*. Each line of data includes the hour, the minute, the second (always zero), the northing coordinate in meters, the easting coordinate in meters, the frequency in megahertz, the antenna angle in degrees, the data real part, and the data imaginary part. The format is as follows:

hhmm:ss/xxxxxxx.xxxx/xxxxxxx.xxxx/xx/xxx.xxx/sx.xxxxxxxEsxxxx/sx.xxxxxxxEsxxxx//

The file names are *264gprcp.hdr, 265gprcp.hdr, 266gprcp.hdr, 267gprcp.hdr, 264gprcp.dat, 265gprcp.dat, 266gprcp.dat,* and *267gprcp.dat*.

3.4 Processed Data

The processed data, i.e. the results of our measurements and analysis, are included on a 3.5-inch diskette in the Excel file, *BattelleJPGIVResults.xls*, using the spreadsheet template provided in the Demonstration Work Plan. We included the estimated length of the ordnance targets in the “Comments” column. The “Azimuth” column contains a single angle, but due to the ambiguity in the system, the actual angle may be that angle plus any multiple of 90 degrees. A prioritized list ranking the ordnance targets such that the first target is the most likely UXO and the last target is the least likely UXO is included on the 3.5 inch diskette in the Excel file *PriorityList.xls*.

4 Conclusions

Due to the nature of our system, the direct results of the processing are the depth of the target, shape of the target (linear or non-linear), the azimuth orientation of the target, and the length of the target. We were able to classify targets as ordnance or non-ordnance based on the presence of linear shape characteristics. There is no measurement associated with our system from which we can estimate the weight or declination of the target. We estimated the length of each target using the natural resonance frequency extracted from the data. In the future, it may be possible to use a more sophisticated form of complex natural resonance analysis to estimate the diameter of a target, but at this time we can not estimate the diameter. Some of the ambiguity of the azimuth orientation measurement can be removed in future data sets by using both the cross-polar and co-polar data for the analysis.

5 References

[1]Chen, C.-C., and L. Peters, Jr., “Buried Unexploded Ordnance Identification via Complex Natural Resonances”, *IEEE Transactions on Antennas and Propagation,* Volume 45, Number 11, November 1997, pp. 1645-1654.

FINAL REPORT

CONCEPT ENGINEERING GROUP, INC.

REMEDIATION DEMONSTRATION

AT

JEFFERSON PROVING GROUND

FOR

JPG IV

Submitted by:

Jerome Apt, Jr., P.E.
Project Manager
December 9, 1998

NOVEMBER 2-5, 1998

1.0 INTRODUCTION

1.1 Company description.

Concept Engineering Group, Inc. (CEG) was incorporated in 1991 by four principals and is a small business engaged in the design, development and manufacture of safe excavation equipment. It occupies office and shop facilities in Verona, Pennsylvania, a Pittsburgh suburb. It has designed and built safe excavation systems as small as 80 pounds and measuring 2 feet by 4 feet for non-damaging horticultural purposes to a large trenching machine weighing 34,000 pounds and measuring 37 feet long by 9.5 feet wide by 11.5 feet high capable of excavating trenches 6 feet wide by 10 feet deep. The company's design team operates totally with CAD equipment and the shop space is capable of metal fabrication and assembly of both prototypes and production runs of small quantities of equipment for commercial sale.

1.2 Project Team and Roles

Jerome Apt, Jr., P.E. – Project Manager
Richard D. Nathenson, P.E. – Technical Oversight
Paul M. Brumbaugh – Equipment modification design
Kevin Kovalski – Field Technician

1.3 Subcontractors and Team Members

There were no subcontractors utilized on this project.

2.0 DEMONSTRATED TECHNOLOGIES

2.1 Remediation System and Transport Mode

CEG's premier technology is the company developed and patented supersonic air jet nozzle which uses compressed air from any standard commercial air compressor and converts the discharged air to a focused jet moving at mach 2, twice the speed of sound. This focused jetstream of supersonic air enters pores in the ground and expands as it loses velocity and explodes the surrounding soil. These jetstreams do not impact non-porous items buried in the excavation. The supersonic air jets will not damage pipe, conduit, fiber optic cable with which contact is made. CEG then utilizes its secondary technology, a high velocity vacuum system, to remove the disturbed soil from the excavation, permitting the supersonic nozzles to attack fresh soil.

CEG first tested this technology, supersonic air jets coupled with a high efficiency vacuum system at JPG II with the large 34,000 pound machine mentioned above. This equipment was designed as a trenching machine to operate in an urban environment on firm, level ground and not as an off-the-road, rugged terrain vehicle. However, the work done at JPG II performed sufficiently good enough to encourage the company to pursue the remediation of both UXO and AP and AT mines. In 1996 CEG constructed a system for the U.S. Air Force at Tyndall Air Force Base that was coupled to and mounted on a large bucket excavator (A John Deere 690C). This is a six-wheeled machine and the combined weight of the excavator and the CEG equipment trailer and separator (mounted on the dip stick of the 690C) exceeds 47,000 pounds. This unit is still at Tyndall Air Force Base awaiting testing and evaluation.

During this same period, 1996-1997, CEG under contract to the U.S. Army, CECOM at Ft. Belvoir, VA, developed a small, light weight portable gas-engine compressor unit (<290#) to supply compressed air to CEG's AIR-SPADE™ hand tool to safely expose anti-personnel mines of all types. This development was successfully tested at Ft. A.P. Hill, VA and currently there are AIR-SPADE™ units in Cambodia, Afghanistan and Angola. As part of this U.S. Army contract, CEG developed a small air jet/vacuum system to safely expose anti-tank mines. This unit was designed to be as compact as possible so that the entire system could be mounted on a small all-terrain vehicle. The result was the SAFEX™, Jr., which has been successfully tested at Ft. A.P. Hill, and with CECOM's permission was the unit demonstrated at JPG IV. A photograph of this system is shown below.

SAFEX™, Jr. at JPG IV 11/03/98

The SAFEX^{TM}, Jr. is self-contained and is powered by a 24HP air-cooled gasoline engine which drives a 300 scfm, 9”Hg positive displacement vacuum pump and a 70 scfm, 150 psig rotary screw air compressor. The vacuum pick up hose is 3” diameter vacuum hose capable of withstanding 12” Hg vacuum. The air compressor supplies compressed air to a CEG AIR-SPADE^{TM} hand tool. The entire system is mounted on a John Deere 6X4 Gator all-terrain vehicle powered by an 18 HP water cooled gasoline engine. The flotation type tires give this unit a very low ground pressure, 6 psig.

2.2 Recommended Applications and Technology Limitations

The system demonstrated is a non-contacting excavation system, as such it can safely be used by trained personnel to totally expose UXO once the ordnance has been located by a reliable detection system. After exposure, the UXO can be deactivated and removed or destroyed in place. If desired, the entire system may be configured to be remotely controlled however, the CEG supersonic air jets do not exert sufficient force to trigger UXO.

The limitations of this system are that is slower than a larger backhoe machine but it is far safer. The contacting type excavators can easily trigger UXO and cause damage to the machine and endanger personnel and property.

2.3 Logistics Requirements

The entire system is transported on a single axle trailer having a gross vehicle weight of 3500 pounds and is easily towed by a 1 ton pick up truck. The Gator is not a licensable vehicle and connot be driven on a highway.

2.4 Data Acquisition

All data acquisition was performed manually using a stopwatch, measuring tape, a soil moisture measuring instrument and a soil strength measuring device.

2.5 Data Processing and Interpretation

All data was entered into two Excel spread sheets. The data required in accordance with the contract is detailed in section 4.2.

2.6 Quality Assurance

The operation of the system and the accuracy of the data acquisition were controlled by the CEG project manager.

3.0 DEMONSTRATION RESULTS

3.1 Assumptions

The only assumptions made were that the flags placed on the surface accurately designated the location of the suspected UXO.

3.2.Site-Specific Procedures

The system was driven to the flag designating the suspected target, and excavation was begun. Travel times were recorded for several locations, however since the Gator traveled at the same speed between all targets, not all travel times were logged. The stopwatch was started and then stopped when the target was encountered. When the ordnance or non-ordnance was uncovered the on-site ordnance specialist was summoned to identify the uncovered target.

3.2 Problems Encountered

Three problems occurred. A spring shackle weld failed on the trailer on the way to the site on Monday morning, which delayed the start by approximately 3 hours. Wet soil clogged the vacuum hose on a few occasions requiring some minor lost time to clear. The third problem occurred on Thursday. The 24HP engine fuel filter became clogged causing the engine to stall. A trip to Madison was required to purchase a new filter, creating about 2 hours of down time.

3.3 Discussion of Results

CEG felt that the results of the demonstration were excellent. In all, 30 targets were uncovered and all targets were fully identified. The excavations were well defined with surgically cut vertical side walls.

Typical excavation at JPG IV

4.0 DATA

See attached spreadsheet.

5.0 Conclusions

The system worked successfully and will operate even more efficiently when the hand tool and vacuum hoses are attached to an overhead control mechanism, a modification to be made as a result of this JPG IV demonstration.

ENSCO, Inc.

Jefferson Proving Grounds Phase IV Technology Demonstration

October 2, 1998

Subcontract No. S0075-97-UXO-JPG4-002

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Greensboro, NC 27404
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Prepared by:
ENSCO, Inc.
5400 Port Royal Road
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(703) 321-9000

1.0 Introduction

ENSCO, Inc. conducted a demonstration at Jefferson Proving Grounds on August 31 – September 4, 1998, of our ability to characterize and identify various buried unexploded ordnance (UXO) targets.

1.1 Company Description

ENSCO, Inc. has been active in geophysical sensor development and geophysical services for all of our 25-year history. Our current staff of 600 people is working in a variety of technology and sensor areas including seismology, ground-penetrating radar, electromagnetic methods, sensor fusion and multi-spectral imaging. We acquired one of the early patents in ground-penetrating radar (GPR) approximately 20 years ago with our Synthetic Pulse Radar and have continuously worked to improve both hardware and interpretation techniques to make GPR more effective in numerous application areas. The demonstrated *MagnaLog* magnetic sensor was developed by ENSCO.

1.2 Project Team and Roles

ENSCO's field team consisted of three individuals: Dr. David Taylor, Mr. George Fields, and Mr. Edward Hull. Dr. Taylor was the Project Manager and Field Team Leader. Dr. Taylor and Mr. Fields conducted data analysis. All field team members participated in data acquisition.

1.3 Subcontractors and Team Members

No subcontractors were used for this project.

2.0 Equipment Data

ENSCO deployed three technologies: i) *MagnaLog* magnetic sensing system, ii) Sensors & Software pulseEKKO 1000 GPR system, and iii) Geonics EM-61 electromagnetic sensor. Each will be discussed in turn in the following sections.

2.1 Sensor System and Transport Mode

i) *MagnaLog*. MagnaLog is a hand-held, digital vertical magnetic gradient sensor array and data acquisition system developed by ENSCO. Employing two Schonstedt GA-72-CD sensors and an on-board microcontroller, *MagnaLog* was designed for very rapid magnetic data collection for UXO targets. The data collection rate along profile lines is user selectable. For this project we used 10 samples/sec, resulting in a spatial sampling rate of approximately 10-15 cm. The operator wears the system comfortably from the shoulders. The microcontroller has a 12-button keypad to setup data collection parameters. During data collection, the operator only has to use a single push-button to interact with the system. Position data is acquired by walking profile lines of known length. The *MagnaLoc* processing software interpolates data positions based on a constant walking speed and start and end positions of the profile.

ii) pulseEKKO 1000. The pulseEKKO 1000 is an off-the-shelf portable, digital ground-penetrating radar system manufactured and marketed by Sensors & Software, Inc. We transported the system in a garden cart to locations where we would collect data. Then, data are acquired by dragging the antenna pair along the ground. We primarily used 900 MHz antennas.

iii) EM-61. The Geonics EM-61 is a common off-the-shelf electromagnetic (EM) induction sensor system. The EM-61 can be configured in two modes. The first mode is the standard EM-61 system

with 1-m square coils configured as a wheeled cart that an operator pulls. The second mode is a smaller pair of coils, also configured with wheels, that is called the EM-61HH, or hand-held EM-61. We primarily relied upon the EM-61HH, using the 1-m coils only for deeper targets. Both configurations are wheeled sensors that are towed by an operator.

2.2 Navigation

The target locations were provided to us via plastic pin flags and embedded wooden hubs. For each target we investigated, we used the pin-flag location as the center of a local coordinate system. We established a 5-m by 5-m local grid surrounding the pin-flag using a fixed frame that was oriented to magnetic north. This local grid was used to guide data acquisition.

i) *MagnaLog*. Magnetic data were acquired walking north-south profiles between markers on our local grid.
ii) pulseEKKO 1000. GPR data was acquired on profile lines oriented to the corners of the local grid. A plastic rod was used to mark positions along the profile lines.
iii) EM-61. EM data were acquired walking north-south profiles between markers on our local grid.

2.3 Data Processing System and Data Analysis Methodology

All data processing was accomplished on personal computers (PC).

2.3.1 Individual Sensors

i) *MagnaLog*. Magnetic data were downloaded to a PC in the field. Post-processing attached X-Y coordinates, removed trends and biases in the data, generated contour plots, and extraction of parameters. Magnetic data were modeled using a finite-length dipole model to extract target orientation and moment. All magnetic processing software was ENSCO-developed.
ii) pulseEKKO 1000. GPR data were acquired on a PC in the field and were immediately available for analysis. Data were initially displayed using the pulseEKKO software provided by the sensor manufacturer. Using ENSCO-developed software, 2-D images were computed and reflection amplitudes were measured.
iii) EM-61. Data were downloaded and X-Y coordinates attached using the DAT61 software provided by the sensor manufacturer. ENSCO-developed software removed trends and biases in the data, extracted parameters, and displayed results.

2.3.2 Sensor Fusion

Sensor fusion was accomplished by determining the best match of each target to the reference data set acquired at the 80-acre test site. At the 80-acre site we had collected data for all three sensors over a suite of UXO and non-UXO targets. By comparing data from each target in the demonstration area to those “known” data from the 80-acre site, we classified each target according to the best match. This comparison was initially accomplished quantitatively, then verified and validated by visually inspecting the data displays.

2.4 Instrument Limitations

i) *MagnaLog*. *MagnaLog* is designed for rapid, inexpensive magnetic gradient surveying. It is particularly effective for detection of shallow (< 3 m) ferrous objects. As a magnetometer system, *MagnaLog* will not detect non-ferrous objects. *MagnaLog* can operate in most any climatic conditions.

ii) pulseEKKO 1000. As a GPR system, the pulseEKKO 1000 is used for characterizing subsurface conditions. GPR is most effective in resistive soils. Conductive soils contribute to signal attenuation. GPR can be unusable in highly conductive soils. As a surface-contact sensor, GPR requires relatively uniform surface conditions for optimal results. The pulseEKKO 1000 has not been ruggedized for use in rain, extreme heat, or freezing temperatures.

iii) EM-61. The EM-61 has been on the market for many years. It is not a sophisticated instrument, but it is fairly rugged and usable in most weather conditions. The EM-61 detects all metals. It has been demonstrated to have difficulty in very rough terrain, where the cart may bounce erratically, and in ferrous soils which can have locally variable patches of high conductivity.

3.0 Demonstration Results

3.1 Data Acquisition

ENSCO completed data acquisition of all 160 targets within the 40-acre site (numbered 1-160), plus the 10 additional targets (numbered WES1-WES10) with all three sensors. Completion of all targets with all sensors within the 40-acre area required approximately 24 hours of field time for the three-man field team. An additional approximately 11 hours was spent reoccupying some target locations and documenting terrain features at each target, resulting in a total of approximately 35 hours expended within the grid collecting data.

3.3 Problems Encountered

For the most part, the demonstration proceeded smoothly. Grass at the site was somewhat high, knee-high in most locations.

The most important problem we encountered was the existence of significant depressions at the site of many target locations. These depressions resulted in vertical offsets of 30 cm or more precisely at the target location. These depressions were the result of compaction and settling into the excavation. At our self-test at the 80-acre site, this problem was severe. At the final demonstration, we had expected the surface features at the target locations to more closely correspond to the native surface conditions. That was not the case.

These depressions appear to be due to the method of emplacement and hence are an artifact of the demonstration set-up. The effect of these depressions will vary with the type of sensors used. Hand-carried magnetics, for example, will be minimally affected if the operator chooses his steps carefully. Wheeled electromagnetics will be affected due both to the bounce and rapid variations in sensor height relative to the target.

GPR will be the most significantly affected sensor technology because this method requires contact of the antenna with the ground surface. At different locations, the steep depressions made it impossible to keep the antenna on the ground surface, cause spatially variable changes in the orientation of the antenna (over lateral distances of only centimeters), and rapidly vary the distance from target to antenna.

We found these depressions to be a significant problem with acquiring and interpreting GPR data. While no UXO site is pristine, these “bath-tubs” (as they appear) are strictly an artifact of the emplacement method (backhoe). As such, we believe the site set-up is biased against our demonstration and any other demonstrator who uses GPR.

4.0 Digital Data

4.1 Raw Data

All raw digital data are provided on the attached ZIP disk.

4.2 Processed Data

Our interpreted target results are provided on 3.5-inch diskette. Also included on the diskette is a copy of this report.

FINAL REPORT
GC-FR-98-3293

VEHICULAR MULTISENSOR ARRAY WITH ENHANCED UXO DISCRIMINATION PROCESSING For the PHASE IV CONTROLLED SITE ADVANCED TECHNOLOGY DEMONSTRATIONS U.S. ARMY JEFFERSON PROVING GROUND, MADISON, INDIANA

Prepared by

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for

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November 1998

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1.0 INTRODUCTION

1.1 Company Description - GEO-CENTERS, INC. (7 Wells Avenue, Newton Centre, MA, 02159, 617-964-7070) has been a major contractor in the unexploded ordnance (UXO), explosive ordnance disposal (EOD) and countermine research communities for the last 18 years. GEO-CENTERS designed, developed and constructed the prototype Surface Towed Ordnance Locator System (STOLS®) in 1988 and commercialized this technology as the second-generation STOLS® in 1993.

1.2 Project Team and Roles - The Program Manager for this effort was Mr. Richard Russell, Director of the Products Development Group at GEO-CENTERS, INC. The Project Manager and field team leader for GEO-CENTERS was Mr. Alan Crandall, GEO-CENTERS' Senior Project Engineer. Mr. Robert Siegel, Mr. Jonathan Daniels, Mr. David Varjian and Mr. Richard Kimball assisted him, in the Phase IV field operations. Mr. Bruce N. Nelson, Principal Scientist, managed the enhanced data processing task and, was the primary developer of the fuzzy inference system that was used for target classification and prioritization on this effort.

1.3 Subcontractors and Team Members - A team from the University of Missouri was responsible for image processing, feature extraction, providing graphical signatures (from both Electromagnetic induction sensor and Magnetometer data) of all interrogated targets. They assisted in the development of the fuzzy inference system that was used for target classification and prioritization. This subcontractor team was headed by Professor Paul Gader and supported by student Mr. Ali Koksal Hocaoglu.

2.0 DEMONSTRATED TECHNOLOGIES

2.1 Sensor System and Transport Mode - Vehicular, surface towed, concurrent, multisensor capability; Total field/gradiometer magnetometer array (up to 8 Geometrics 822A cesium vapor magnetometers with 0.5 meter spacing updating at 20 Hz, arrayed four over four with a 15" vertical separation, on a towed platform); Electromagnetic (EM) pulsed induction sensor array (3 Geonics EM61, half-meter coils, upper and lower, updating at 10 Hz, on front-mounted platform); Tow vehicle and sensor platforms designed for low magnetic and pulsed induction self-signatures; Electronics optimized for low magnetic and electromagnetic noise; Trimble differential GPS with Real Time Kinematic (RTK) for real-time 3 to 5 cm precision; Self-contained transport in tractor-trailer; trailer becomes an on-site command/maintenance/data processing center; Same day production of images of magnetic and EM data; Enhanced data processing for feature extraction and target classification.

2.2 Recommended Applications and Technology Limitations - STOLS® has been successfully deployed on over 70 commercial surveys spanning UXO, HTRW, landfill, underground storage tanks, archeological, and utility mapping applications. Magnetometers are not optimally fielded in areas where there are high concentrations of magnetic rock or other local high spatial frequency magnetic gradients or in areas where nonferrous metals are of interest. However, magnetometers configured in a gradiometric configuration and augmented by an array of electromagnetic induction sensors alleviate these limitations.

2.3 Logistics Requirements - STOLS® is a self-contained survey system.

2.4 Data Acquisition - STOLS® technology is a trilogy of total field magnetometer, total field gradiometer, and electromagnetic (EM) pulsed induction sensors integrated with DGPS.

2.5 Data Processing and Interpretation - On-site data processing uses a Silicon Graphics Unix workstation to combine the sensor data with the DGPS data and create spatially registered data images of the surveyed area. Data processing involves time-correlating and subtracting the reference magnetometer data from the vehicular magnetometer data, correcting for errors in the navigation and heading data, individually calibrating the sensors, and interpolating the sensor data onto a 10 cm grid for visual display.

Areas of interest were defined (based on the observed magnetometer and EM signatures at the provided Northing and Easting coordinates) for each of the 160 targets. With respect to the magnetometer data, morphological geometrical feature extraction methods were used to analyze the areas of interest. Specifically, for both the positive and negative lobes a series of geometric features are extracted. In addition, other features including the orientation of the two lobes, a scaled length parameter, and the positive lobe contrast and negative lobe contrast is extracted. With respect to the electromagnetic induction sensor data, a feature representing the signal contrast was extracted from the area of interest.

The methods that were developed and used to analyze these features are based on a detailed analysis of the GEO-CENTERS' data collected during the JPG3 demonstration. This work was performed under other externally and GEO-CENTERS sponsored programs. Specifically, data collected over targets of the class that were expected to be encountered during the JPG4 demonstration and data collected over appropriate clutter items were analyzed to develop classification and prioritization methods. Two methods have been developed and are described below.

The first method involves first using a feature analysis software package to identify the data features that best separate UXO from clutter. Clustering algorithms are then used to define target prototypes for both UXO and clutter. Features are extracted from the blind data and distance measurements (in the multi-dimensional feature space) are then made to both the target and clutter prototypes. The distance from the clutter prototype is then subtracted from the distance to the target prototype. When this difference signal is negative (i.e. the distance to the target (UXO) prototype is less than the distance to the clutter prototype) the target is classified as ordnance. When the difference to the target prototype is positive the target is classified as clutter. The data are sorted in ascending order to determine the target priority. This method was not employed in support of this program, as it was feared that the target and clutter prototypes were too specific to the JPG3 demonstration. If GEO-CENTERS had had the opportunity to survey known targets of similar types as part of the JPG4 evaluation and these data were used to augment the training set, then this method would have been given greater consideration.

The second method involves the use of a fuzzy inference system. A combination of expert input (based on previously observed ordnance and clutter signatures) and the JPG3 data sets were used

to develop the feature space, membership functions, and rule sets that are used in this inference system. Final tuning of the fuzzy inference system was performed using the JPG3 data sets. The fact that this system was based in part on expert input and not training was why this method was employed in support of this program.

A five feature space was used in the fuzzy inference system. Specifically, the pattern spectra mean of the positive lobe, the pattern spectra mean of the negative lobe, the orientation of the lobes, the positive lobe contrast and the difference between the positive and negative lobe contrasts were used as input to the inference system. The fuzzy inference system analyzes these data and outputs a confidence associated with a given target. The higher the confidence the more likely a declared target is ordnance. The targets are prioritized based on this confidence value. The JPG3 data sets were used to determine a specific confidence level threshold for. Target classification and prioritization were initially performed using the fuzzy logic inference system.

Following the initial classification and prioritization, the magnetometer and electromagnetic pulsed induction sensor signatures (images) were analyzed through observation and as required targets were moved up or down in priority (and if appropriate, were reclassified as ordnance or clutter). Primarily it was cases where there was a very weak magnetometer signal and a discernable electromagnetic sensor signature or cases where the morphological feature extraction may have produced an erroneous value (based on an observation of the signature) that resulted in target reclassification or a reprioritization of the target list. With more appropriate training data, GEO-CENTERS believes that the methods employed could be completely automated.

2.6 Quality Assurance - System status indicators are provided to the operator during operations with on-line data quality checks and alarms. Data are downloaded several times per day during survey operations and immediately displayed and pre-processed to validate system performance and to document coverage to date. Any suspect data is reacquired, if necessary. Daily coverage maps are provided so that progress can be assessed, monitored and documented. Control monuments and other known locations are overlaid on sensor image data to confirm that the DPGS is accurate.

3.0 DEMONSTRATION RESULTS

3.1 Assumptions – The primary assumption in the data analyses were that the methods that were developed based on the JPG3 data could be used to refine and tune the classification and prioritization system for the JPG4 demonstration. A total of 61 targets (of the same type that were to be encountered in JPG4) and approximately 50 emplaced clutter items from GEO-CENTERS' JPG3 data set were used to tune the classification and prioritization systems. Specifically, it is the appropriateness of the emplaced clutter that was associated with the JPG3 demonstration that presents a concern. If this class of clutter items were not representative of the clutter items emplaced at JPG4, the results from this activity would be effected. It was because of this possibility (probability) that the fuzzy inference system based method was used for target classification and prioritization. GEO-CENTERS suggests that both of the methods that are used for classification and prioritization would have benefited greatly if there was an opportunity to

collect data (with ground truth) over buried targets and clutter of the same class that were emplaced in JPG4.

In addition, many targets were classified at the same confidence value. In these cases, the targets are prioritized in ascending order based on their assigned numbers. This is indicated in the provided table by the provided target confidence value. Also a review of these confidences provides an indication of where priority changes or re-classification of targets were performed in the final review of the data.

3.2 Site-Specific Procedures - GEO-CENTERS surveyed area 3, the Waterways Experimental Station (WES) area, Area 2, Area 1 and Area 4 with a single mob/demobilization. Area 3 and the WES area were surveyed on the first day after system set up. Area 3 was resurveyed that day, due to a failing magnetometer. Area 2, Area 1, and Area 4 were surveyed on the second day, completing the required data acquisition. All areas were surveyed with the sensors at a 6" height. Areas were generally covered in a direction determined by each area's longest dimension (e.g. East/West or North/South). Individual lines of data were tailored by target locations so some lines are longer. On the third day, the sample clutter and UXO objects were visited and a request was made to acquire some test data over selected items. Two lines were established, one with surface laid UXO samples and one with surface laid clutter items. Data was acquired at 6" and 12" sensor heights at two object orientations (North/South and East/West). STOLS® was then packed and demobilized from the site.

3.3 Problems Encountered - A magnetometer repaired just prior to the demonstration failed during the first survey of Area 3 and was replaced with a spare for the remainder of the field demonstration. Rainy weather slowed progress on the third day but did not cause any shutdowns.

3.4 Discussion of Results - Results are provided in a Microsoft Excel spreadsheet called geocen4.xls. For analysis, the survey area was broken up into four separate sites reflecting areas 1-4. During analysis, the score provided in the table is the confidence that is output from the fuzzy inference system. The table was initially sorted by this value. When these numbers are out of sequence (i.e. not in descending order) it indicates that a target priority was changed as a result of the final review of the data. In cases where the confidences are of equal value, no efforts were undertaken to further prioritize the data. The classification of targets as ordnance in the table is also developed from the confidence. In general targets are classified as ordnance when the confidence value is greater than 0.62 and as clutter when the confidence is below this value. The confidence itself is the best means of ascribing a "high", "medium" or "low" confidence designation to the target. It should also be noted that the separation of ordnance from non-ordnance is not crisp. In the JPG3 training sets there were ordnance items with confidences of .11 and non-ordnance items that were classified as 0.89. This is also indicated by the changes in priority in the table that were made based on the final data review. Lastly, no effort was made to classify items into the "unknown" category. Targets were classified as either ordnance or non-ordnance.

4.0 DIGITAL DATA

4.1 Raw or Semi-Raw Data - The semi-raw data are from the STOLS® data processing computer. The data are semi-raw in that they have been preprocessed for navigation jumps and gaps. Loss of differential link cause momentary jumps. Extended loss of differential link or loss of satellite access cause gaps in position data. The magnetometer sensor data are corrected for time corresponding reference data and sensor to sensor calibration, based on heading. Magnetometer data for each of the four areas are delivered in four separate files. The EM data are calibrated for sensor to sensor offsets. EM data for each of the four areas are delivered in four separate files. The two reference magnetometer data files are from the stand-alone diurnal variation station deployed each day. Each data file is provided with an associated header file. These twenty ASCII, semi-raw data files occupy approximately 64 megabytes. File names (jjjxxxxx.dat) begin with the Julian date (jjj); a GEO-CENTERS' description (e.g. j4ma1) where j4 represents JPG4, the "m" or "e" designates magnetometer or EM data, and the a* designates the area (e.g. area 1). The time provided is in hhmmss.ss format to correspond to the actual time of each sensor update. Latitude and longitude data are in decimal degrees (WGS84). No height data was logged, so this field is filled with an asterisk (*). Sensor values are in unit gammas (nT) for magnetometers, centered around zero. EM data are in unit milivolts. All appropriate navigation, heading, reference magnetometer, and sensor calibration corrections have been applied to the sensor data.

4.2 Processed Data – The results of the enhanced data processing are included in an Excel workbook file named geocen4.xls. This file, along with the digital version of this report, is included on the enclosed floppy disk. The demonstrator identifier is 026. Target: is the provided truth target number. Northing: and Easting: values are also the provided truth locations. Depth: was derived from the traditional STOLS® dipole model match reported on in JPG1, JPG2, and JPG3 reports. Type: targets were classified as either ordnance or non-ordnance. No targets were classified as unknown. Confidence is provided as a numerical value for the reasons discussed in Section 3.4 above. Target weights were not determined so this field is filled with "not determined." Target size, azimuth, and declination were derived from the traditional STOLS® magnetic dipole model match. Target class was not determined.

5.0 CONCLUSIONS

STOLS® functioned nearly flawlessly, acquiring the four area surveys and WES area data in just two days, less than 16 survey hours (including area 3 resurveyed). The only system of its kind in the world, STOLS® simultaneously acquires high-resolution, DGPS-integrated total field magnetometer, gradiometer, and electromagnetic pulsed induction data.

The methods that were employed to classify and prioritize targets can be easily applied to STOLS® data in the future. The methodology involves identifying areas of interest (where there are target signatures) from the site map (using the STOLS® software), extracting features from these areas of interest and feeding these feature values into a fuzzy inference system for target classification and prioritization. They will have no impact on STOLS® fielding and little or no impact on the time required to perform data analyses. With a larger amount of appropriate training data (high quality data with ground truth) the techniques employed can be completely

automated. The employed techniques promise to provide a robust means for UXO classification and prioritization using STOLS® data.

Development and Application of Technologies for the Discrimination and Classification of Buried Unexploded Ordnance – Phase IV

Geophex Progress Report 03 – **Final Report**
October 14, 1998

Prepared by:
Geophex, Ltd.

Subcontract No. S0075-97-UXO-JPG4-005

Submitted to:

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Final Report

on

Development and Application of Technologies for the Discrimination and Classification of Buried Unexploded Ordnance – Phase IV

1.0 Introduction

1.1 Company Description

Geophex, Ltd. is an environmental science and engineering firm founded in 1983. Geophex is a corporation licensed in both engineering services and geological services by the State of North Carolina. The firm specializes in environmental, geological, and geotechnical services, as well as a variety of non-intrusive geophysical technologies for investigating subsurface conditions of natural and man-made environments. In addition to our Raleigh headquarters, Geophex maintains offices in Richmond Virginia, Macon Georgia, and Boston Massachusetts.

Geophex is in a unique position to develop techniques for differentiating UXO from non-UXO. We have designed and developed the only hand-held, multifrequency EM sensor (known as the GEM-3) capable of efficiently and economically measuring multifrequency electromagnetic (EM) data for discrimination analysis. In addition to possessing a comprehensive understanding of the GEM-3s functionality, our scientists have extensive field experience and formal training.

The focus of our R&D instrumentation program has been electromagnetic induction sensing techniques. Our initial project was the design and development of a unique, multifrequency, airborne electromagnetic sensor requiring only a single set of sensor coils. Subsequent activity has involved fabrication of man-portable electromagnetic instruments (GEM-2, GEM-2H, GEM-3, and GEM-5). We developed the initial prototype GEM-3 for the JPG Phase III demonstration.

1.2 Project Team and Roles

Our Project Team consisted of scientists from Geophex and AETC, Inc. There were no fixed roles – each company participated in all phases. Geophex provided the GEM-3 sensor and associated hardware. AETC provided assistance throughout all phases of the program and were primarily involved with the development of multivariate discrimination software. The project was a team effort.

1.3 Subcontractors and Team Members

Geophex subcontracted AETC, Inc. to participate in the JPG Phase IV program. The project was lead by Drs. Dean Keiswetter and I.J. Won, Geophex. Drs. Tom Bell and Bruce Barrow were key team members from AETC, Inc.

2.0 Demonstrated Technologies

2.1 Sensor Systems and Transport Mode

The basis of our classification analysis was broadband EM data acquired by the GEM-3 sensor. The GEM-3 uses a pair of concentric, circular coils to transmit a continuous, wideband, digital, EM waveform. The resulting field induces a secondary current in the earth and nearby conductive bodies (such as UXO). The set of two transmitter coils, with precisely computed dimensions and placement, creates a zone of magnetic cavity (i.e., an area with a vanishing primary magnetic flux) at the center of the two coils. A third receiving coil is placed within this magnetic cavity so that it senses only the weak, secondary field returned from the earth and buried targets. All coils are molded into a single, light, circular disk in a fixed geometry, rendering a very portable, monostatic sensor head. The removable electronics package controls system operations and stores the digital data.

Figure 1. Photograph of the GEM-3.

To compliment the GEM-3 data, we acquired magnetic data using a Geometrics cesium-vapor magnetometer (G-858). The two data sets provided independent estimates of target size, location, and depth. Both sensors are man-portable and require minimal field logistics.

2.2 Recommended Applications and Technology Limitations

The GEM-3 is ideally suited for investigations of buried UXO and landmines. It is designed to have a small footprint, minimal logistic requirements, and can be programmed in the field for user-defined bandwidth.

The primary limitation of the GEM-3 relates to its prototype status. The sensor is relatively new (it was developed a few years ago) and we are still learning how to capitalize on its capabilities and potential. We have recently developed a new coil design that will improve the sensors' sensitivity and depth penetration.

2.3 Logistics Requirements

The GEM-3 and G-858 require minimal logistical requirements. The primary logistics relate to charging the sensors' batteries.

2.4 Data Acquisition

For each target, we acquired GEM-3 data at 25 points that were evenly spaced over a three-foot by three-foot grid, centered directly over the target. At each spatial location, we acquired data at eight frequencies (30, 90, 210, 510, 1350, 3570, 9210, and 23970 Hz). The data were downloaded to a field computer in realtime for storage and analysis.

For each target, we acquired total-field magnetic data over a 20-foot by 20-foot area centered directly over the target. We used dead-reckoning procedures for spatial registration. We acquired magnetic data using a 10-Hz sampling rate, resulting in one data point every four inches, and surveys lines spaced one-foot apart.

2.5 Data Processing and Interpretation

Our classification of UXO versus non-UXO was based on how well the EMI target signatures (unknown object) matched that of our signature library (known objects). The signature library, as used here, consists of multifrequency GEM-3 data for each ordnance and non-ordnance item at multiple depths and orientations.

We used two partially independent matching procedures. The first directly compared the measured data (amplitude and phase) to our signature library. Figure 1 shows a snapshot of the program for target number five. In this example, the unknown target signatures match extremely well to that measured for a 20mm measured in free space. Without going into detail, the triangles in Figure 1 represent target signature picks, while the asterisks represent data from the signature library.

The second processing procedure is based on the spatial and spectral response of the unknown target. We refer you to an article by Dr. Yogadhish Das et al., 1990, for details.

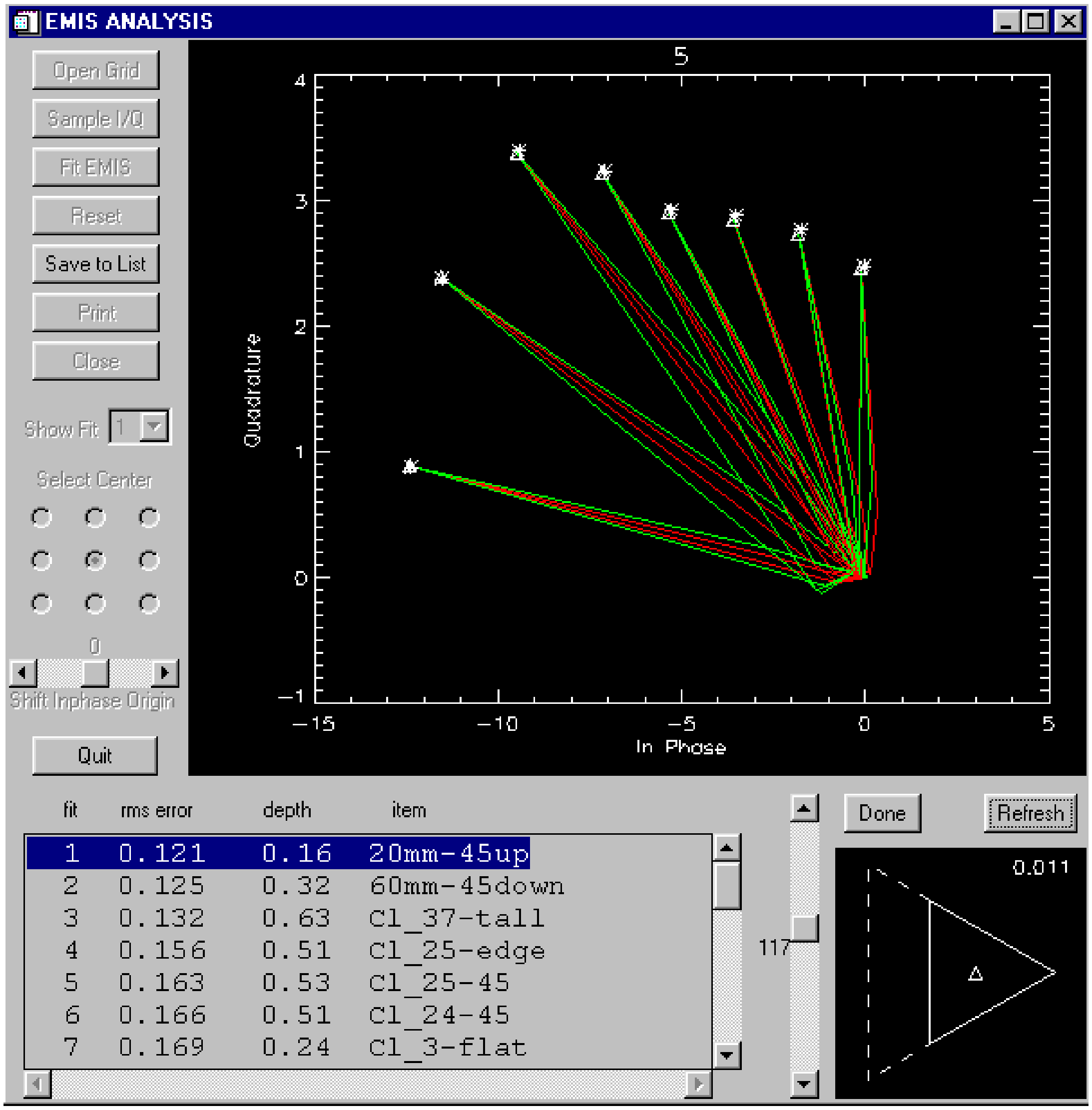

Figure 1. Computer screen snapshot of a discrimination algorithm.

2.6 Quality Assurance

The GEM-3 and G-858 have internal data quality checking software. In addition, we processed each data before leaving the site to assure high data quality. As a result of our in-field analysis, we reacquired data at approximately six grids (magnetic and GEM-3 combined). At these sites, human error was the problem.

3.0 Demonstration Results

3.1 Assumptions

The primary assumption implicit in our discrimination approach is that the EMI spectral response measured for each target in air does not change when the object is buried.

3.2 Site-specific Procedures

No site-specific procedures were used – all grids were approached the same.

3.3 Problems Encountered

No problems were encountered that merit discussion.

3.4 Discussion of Results

Our results have been input into the recommended Excel® spreadsheet and are provided on the attached ZIP disk. In addition to the required fields, we listed which item we think is present at each target location. In some cases (i.e., combinations of target composition, orientation, and shape) it is difficult to distinguish an elongated clutter item from an elongated ordnance item. In these cases, we based our ordnance/non-ordnance decision on the best fit, and listed our top two to three picks in descending order in the comments section. The 'cl-#' designations listed in the comments section refer to a particular clutter item as designated by Geophex.

4.0 Digital Data

4.1 Raw Data

Our discrimination decision was based on the measured frequency-dependent EMI response. The GEM-3 data, therefore, are formatted according to the specifications listed in the JPG Phase IV Demonstration Work Plan and provided on a PC formatted ZIP cartridge.

4.2 Processed Data

Our discrimination software reads the raw data, compares them to our signature library, and displays the result on the computer screen. There are no processed data files to include.

5.0 Conclusions

As a team, we learned a lot during the past few months and thoroughly enjoyed the opportunity to participate in this program.

Based on our results to date, we believe that broadband EMI data possess enough information to accurately determine if an unknown object is ordnance or clutter. The devil is in the details, however, and although we have gained a fair understanding of the causative phenomenology, we believe there is a lot more work to do. Future challenges involve basic research regarding the underlying physics as well as designing and fabricating an improved GEM-3.

6.0 References

Das, Y., McFee, J., Toews, J, and Stuart, G., 1990, IEEE Trans. Geoscience and Remote Sensing, **1**, p. 278-288.

Appendix

Geophex JPG-IV Results

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Ref: PRCE - 97151

Demonstration of Technologies for the Discrimination, Classification and Remediation of Buried Unexploded Ordnance – Phase IV

FINAL REPORT – UXO DISCRIMINATION TECHNOLOGY DEMONSTRATION

Date of Submission:

19 November 1998

Prepared by:

Geophysical Technology Limited
under Subcontract No. S0075-97-UXO-JPG4-007
in full satisfaction of the requirement

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INTRODUCTION

Geophysical Technology Limited (GTL) of Box U9, Armidale, NSW, Australia, demonstrated its proprietary UXO discrimination technologies at Jefferson Proving Ground, Madison, Indiana, from 19 to 24 October, 1998.

The complementary TM-4 (magnetometer) and TM-4ε (multi-period, pulsed electromagnetic induction) technologies were demonstrated at each of the 160 target locations within the 16 hectare test site plus the 10 targets located at the adjacent one hectare WES site. In addition, calibration data were recorded with both instrument systems over the samples of UXO and non-UXO items provided for this purpose.

While it is the objective of GTL to provide an effective discrimination performance on data recorded during a UXO "search" survey, for the purposes of this demonstration and our development program, additional data were recorded at different orientations over each known target site. Discrimination against geological sources was performed in real time. Discrimination between UXO and non-UXO and classification of UXO types were performed in a post-processing strategy that integrated the information provided by each of the magnetic and electromagnetic sensors.

1.1. Company Description

Geophysical Technology Limited (and its antecedent, the Geophysical Research Institute) has operated as a geophysical services provider and instrument developer since 1978. GTL offers sub-surface detection and mapping services, as well as related research services, to the UXO remediation; mining exploration and engineering; and industrial decontamination markets.

GTL has been involved in the development of systems for UXO detection for almost 15 years in collaboration with the Australian Department of Defence. Its staff pioneered the development of the optically pumped magnetic sensor in the late 1960s, built the first portable, digital recording magnetometer in the late 1970s and have performed extensive research into the issues of verifiable UXO search effectiveness and site assessment technologies and methodologies. The TM-4 magnetometer system developed and built by GTL was demonstrated in both Phases I and II of the Advanced Technology Demonstrations by GTL staff under a collaborative agreement with ADI Limited (formerly Australian Defence Industries). The TM-4 and TM-4ε were demonstrated by GTL as a complementary UXO detection system in Phase III of the above program.

GTL operates world-wide providing services directly or through teaming agreements. Its operations span Europe, Middle East, South-East Asia, Australasia and the Americas.

1.2. Project Team and Roles

Key participants in this project were: (those at JPG marked *)

- **Director - Dr John M Stanley*** PhD., (UNE). Director GRI, Managing Director. (TM-4 operator).
- **Project Manager - Stephen M Griffin*** BE (Newc.), BSc, B.Nat Res.(Hons) (UNE), R&D Department. System and data processing development.
- **Senior Geophysicist - Malcolm K Cattach*** PhD., (UNE). Executive Director. (TM-4 operator).
- **Geophysicist - David B Boggs*** BSc (Hons) (UNE). R&D Department. Theoretical development. (TM-4ε operator).
- **Geophysicist - Stephen Billings*** PhD., (Syd). (TM-4ε operator).
- **Geophysicist - Ben Payne*** BSc (Tas). (TM-4ε operator).
- **Electronics Engineer - Ron Bradbury** M Biomed.E. (UNSW). Electronics Department. (TM-4/4ε hardware development).
- **Software Engineer - Ed Campbell** BSc (Hons) (Belfast). Software Department. (Data processing and software development).
- **Visitors and Field Support – Lewis Jones*** BSc (Hons) Adel. Minelab Electronics. **Greg Koennecke*** BMech Eng (Hons) (Adel.) Minelab Electronics.

2. DEMONSTRATED TECHNOLOGIES

The TM-4 & TM-4ε employ the same instrumentation system interfaced with either total field magnetic or multi-period, transient EM sensors respectively.

2.1. TM-4 Magnetometer System

The TM-4 magnetometer is a turnkey data acquisition, processing, interpretation and documentation package designed to efficiently detect and locate ferrous items. It was demonstrated as a two-person, hand-held operation with four, simultaneously recording sensors (Geometrics G822AS) separated by 0.5 metre perpendicular to the survey direction. Total field measurements were automatically recorded at regular 0.05 metre intervals (irrespective of traverse speed) triggered by a cotton thread type odometer.

2.2. TM-4ε Electromagnetic System

The TM-4ε is a turnkey system primarily designed to efficiently detect and locate both ferrous and non-ferrous metallic sources. The TM-4ε system includes hardware/software technologies designed to facilitate discrimination between targets of different electromagnetic properties and different physical dimensions. Discrimination against magnetic minerals in the ground is performed in realtime while other discrimination functions are presently achieved in post-processing. The TM-4ε is able to detect both large and very small (including the detonator of a plastic AP mine) items and able to resolve between items that may be close to each other. The TM-4ε shares the proven TM-4 data acquisition hardware, and data processing, interpretation and documentation software package. The TM-4ε demonstrated used a single, 18 inch diameter coil sensor (Minelab F1A4). Three TM-4ε units were used, each operated by one person. Multi-period, transient EM measurements were automatically recorded at regular 0.05 metre intervals (regardless of survey speed) triggered by a cotton thread type odometer.

2.3. Recommended Applications and Technology Limitations

2.3.1. TM-4 *Magnetometer System*

In EOD applications magnetometers are suitable only for detecting ferrous items. The TM-4 is used to greatest advantage when its survey specification has been optimised for targets deeper than 0.3 metres as a shallow search is most efficiently conducted using the complementary TM-4ε. Multiple magnetic sensors may be used in hand-carried mode in all terrain conditions that are accessible on foot provided the density of trees is sufficiently sparse as to permit the sensor array to pass through or as a towed array in terrain and vegetation conditions that allow access. In heavily vegetated condition a hand-held single sensor configuration may be required. Magnetometers are not well suited to environments containing significant quantities of magnetic mineralisation.

2.3.2. TM-4ε *Multi-period, Time Domain EM System*

The TM-4ε is suitable for detecting all metals, ferrous and non-ferrous. It may be hand-held or vehicle-towed depending upon terrain conditions. The TM-4ε is particularly suited to locating UXO in geological environments that contain magnetic minerals near the surface. Such situations occur in magnetite rich volcanic basalts and in terrains containing laterite. Ability to detect very small, near surface items and to resolve between close targets makes the TM-4ε an ideal complement to the deep search performance of the TM-4. An attribute of the multi-period transmit waveform and subsequent signal processing is the ability to distinguish between the response characteristics of targets of different composition and shape giving this system its ability to discriminate between UXO, mineralised ground and metallic non-UXO having a different shape to UXO.

2.4. Logistics requirements

The TM-4 and TM-4ε systems are designed to be readily transportable and operational with a minimum of logistical support. Both instruments pack into cases permitted for airline travel as personal baggage. Battery charging power requirements can be met from automotive 12 volt supply if mains is not available.

2.5. Magnetic Data Acquisition

The quad sensor TM-4 magnetic data were recorded to 0.01 nT resolution at a sensor elevation of 0.4 metre, with 0.05 metre sample interval along lines and 0.25 metre separation between lines. TM-4 sensors were separated by 0.5 m on an alloy frame. A base-station (Geometrics G856) magnetometer was used recording to 0.1 nT, each five seconds.

At each target site non-magnetic survey chains were established in an E-W orientation (magnetic), 5 metre either side of the target centre. The S-W corner was defined as 0 mE, 0 mN, in local grid coordinates. N-S oriented survey transects between the survey chains were first recorded (4 at a time) at 0.5 metre line separation between 2 mE and 7.5 mE. Infill transects were then recorded between 2.25 mE and 7.75 mE.

Position control along survey lines was determined by cotton thread odometer. Across line control was achieved by the use of visual markers located at the survey chains laid along each end of the survey area. The use of DGPS is optional with the TM-4 but was not used for this application.

2.6. Electromagnetic Data Acquisition

The TM-4ε deployed a transmit/receive coil of 18” diameter operated at an elevation of 0.1 metre above ground. Electromagnetic data were recorded along survey transects at an interval of 0.05 metre.

At each target site non-conductive survey chains were established in both an E-W and N-S orientation, 5 metre either side of the target centre. The S-W corner was defined as 0 mE, 0 mN, in local grid coordinates. N-S oriented survey transects between the survey chains were first recorded at 0.5 metre line separation between 3 mE and 7 mE. E-W oriented survey transects were then recorded between 3 mN and 7 mN.

Position control along survey lines was determined by cotton thread odometer. Across line control was achieved by the use of visual markers located at the survey chains laid along each side of the survey area. The use of DGPS is optional with the TM-4ε but was not used for this application.

2.7. Data Processing and Interpretation

Data processing was performed on a standard IBM-compatible PC with Pentium 300 processor, 64 Mb RAM and 4 Gb HDD.

2.7.1. TM-4 *Magnetic Data*

The TM-4 positional data was corrected by using the control line positions at the start and end of each 10 metre grid. Compensation was also performed to remove the temporal magnetic disturbances recorded at the base-station magnetometer. The data were then high pass filtered to remove interference from geological sources below 10 metres. Next, data validation and QA procedures were performed. The data were recorded using a local coordinate system of origin 7.071 metres S-W of each target position. With knowledge of the WGS-84 location of each target, the coordinates of each data point were then translated to WGS-84 positions. These data accompany this report (Ref: Section 4).

The data interpretation process involved computer-aided, 3-D modelling of each magnetic anomaly and comparison with a UXO knowledgebase that included data recorded over the calibration items provided. The output of this interpretation process was a database file containing position, mass, size, depth and orientation of each target recognised.

2.7.2. TM-4ε *Electromagnetic Data*

The TM-4ε positional data was corrected by using the control line information recorded at the start and end of each 10 metre grid.. This data were then stored as a raw, positioned data file. Next, data validation and QA procedures were performed. The data interpretation process involved classifying the spectral characteristics of each electromagnetic anomaly followed by a statistical fit of these characteristics to a UXO knowledgebase data set that included data recorded over the calibration items provided. The output of this interpretation process was a database file containing the best match of each target response to the calibration set.

2.7.3. *Integrated* TM-4 *and* TM-4ε *Data*

The magnetic and electromagnetic interpretation database files were then integrated in order to:

- take greatest advantage of the optimised deep detection capability of the TM-4;
- detect non-ferrous as well as ferrous targets;
- discriminate against magnetic false negatives using immunity of the TM-4ε to mineralised soil;
- discriminate against magnetic false positives using the discrimination capability of the TM-4ε;
- utilise the TM-4 to best determine the depth of the target; and
- utilise the TM-4ε response to best determine the attitude of the target.

The spreadsheet database file containing the integrated interpretation accompanies this report (Ref: Section 4) and is provided in hardcopy as Appendix 1 of this report.

2.8. Quality Assurance

Quality assurance procedures were applied to each phase of the operation. These included:

- instrument calibration checks with known response source at each power-up and power-down;
- continuous, in-built, instrumentation self diagnostics with audio and visual alerts;
- routine odometer calibration check during data pre-processing;
- routine cross-correlation positional accuracy check during data processing;
- routine image cross-correlation data validation check during pre-processing;
- routine duplication of interpretation modelling; and
- routine data back-up during all stages.

3. DEMONSTRATION RESULTS

3.1. Assumptions

All magnetic and electromagnetic responses were assumed to have as their source one of the UXO or non-UXO items contained in the calibration set. (in this context, items at the WES site were considered as additional calibration items.)

3.2. Site-Specific Procedures

The task-specific requirement to interrogate known, marked targets (rather than search a large area to find them) dictated that hand-carried operation using the in-built odometer and control lines (rather than the optional DGPS) would be the most accurate and effective procedure at this site.

The presence of 60 Hz electromagnetic interference from power lines dictated that the magnetic field be sampled at 200 Hz and then filtered in real time to attenuate the interference. The filtered data were then recorded at regular sample intervals as measured by the odometer.

As a measure to avoid possible interference between TM-4ε units, a minimum 50 metres separation between crews was maintained.

3.3. Problems Encountered

No problems were encountered with any aspect of the operation.

3.4. Discussion of Results

The attached tables summarise the results of the TM-4 and TM-4ε investigations.

4. DIGITAL DATA

4.1. Raw Data

The data accompanying this report have been provided in the format requested. Positional information has been provided in WGS-84 coordinates.

The file naming convention used conforms to the specification. The magnetic data files are given the name:

XXXMGYYY.D01

where:
XXX is the Julian day on which the data were collected
MG designates magnetic sensor data
YYY is the target number (with the 10 WES targets numbered 161 to 170)
D01 signifies that the data were recorded along traverses oriented N-S (magnetic)

The electromagnetic data files are given the name:

XXXEMYYY.D0Z

where:
XXX is the Julian day on which the data were collected
EM designates electromagnetic sensor data
YYY is the target number (with the 10 WES targets numbered 161 to 170)
D0Z Z=1 signifies that the data were recorded along traverses oriented N-S
Z=2 signifies that the data were recorded along traverses oriented E-W

The magnetic data header files are given the name:

XXXMG000.HDR

where:
XXX is the Julian day on which the data were collected
MG000 designates magnetic header data
HDR identifies the file as a header file

The electromagnetic data header files are given the name:

XXXEM000.HDR

where:
XXX is the Julian day on which the data were collected
EM000 designates electromagnetic header data
HDR identifies the file as a header file

4.2. Processed Data

The interpretation results accompanying this report have been provided in the format requested. The database file has been named GTL_JPG4.XLS. A copy of this spreadsheet is included as Appendix 1 of this report.

5. CONCLUSIONS

All 160 target locations in the 16 Ha site and 10 target locations in the 1 Ha WES site were interrogated with both proprietary magnetic and multi-period, time domain electromagnetic instrument systems.

The TM-4ε electromagnetic data in isolation was considered to provide more diagnostic information relating to the classification/discrimination of target sources than did the TM-4 magnetic data in isolation. However, fusion of the two data was found to enhance the process by resolving some ambiguities contained in the individual data sets.

Prior to this demonstration, GTL had determined that the TM-4ε was well able to discriminate effectively against geological sources, metallic wire, fragmentation and drink cans which together provide the most common sources of false alarms in UXO detection. The non-ordnance targets represented in the present demonstration were not considered typical of non-UXO contamination being in many cases “surrogates” of real UXO. However, the similarity of the non-UXO targets to UXO only increased the challenge of the discrimination/classification task. Technologies able to discriminate between the UXO and non-UXO on this site may be assumed to perform much better in real, live-sites conditions.

An objective of GTL’s EOD technologies development program has been to achieve discrimination/classification from the data required to detect the item in the first place thus obviating the additional cost and effort of subsequently “interrogating” targets after they have been located. While some benefits were derived from recording the electromagnetic in multiple survey directions as described here, the experience has indicated that a similar result may be expected from single orientation data.

The discrimination/classification capability of the TM-4/ TM-4ε instrument combination and signal processing strategy demonstrated on this occasion has been the result of very low budget expenditure. The potential of the system for further development is evident and this task is presently limited only by available funding.

TABLE 1
Magnetic Survey Summary

Total number of targets interrogated (incl. WES targets):	170 targets
Magnetic sensor elevation:	0.4 m
Magnetic sample interval along traverses:	0.05 m
Magnetic sample interval across traverses:	0.25 m
Number of magnetic data measurements per target:	4,800
Survey duration:	28 hours
Magnetic measurement system noise:	0.1 nT

TABLE 2
Electromagnetic Survey Summary

Total number of targets interrogated (incl. WES targets):	170 targets
Electromagnetic sensor elevation:	0.1 m
Electromagnetic sample interval along traverses:	0.05 m
Electromagnetic traverse width:	0.5 m
Number of electromagnetic data measurements per target:	2,400
Survey duration:	36 hours
Electromagnetic system noise:	$\pm$5 emu

APPENDIX 1

Spreadsheet of Interpretation Database

DRAFT

Final Report

Geophysical Mapping: Jefferson Proving Ground Phase IV

Submitted to:

Tetra Tech
Madison, Indiana

November 2, 1998

Submitted by:

Sanford Cohen & Associates
97 Central Street; Suite 302
Lowell, MA 01852

(978) 459-4411 (phone)
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Table of Contents

1.0 Introduction

SC&A Inc. proposed to use its well-known expertise to develop a suite of UXO characterization technologies aimed at sharply reducing present false alarm rates by achieving a high level of discrimination between UXO and non-UXO. SC&A Inc. teamed with Foster Wheeler Inc. to conduct field operations. These operations culminated in the field demonstration. SC&A further developed and refined a database approach to discrimination as well as a model-based, analytical approach. These individual approaches were integrated to realize the final discrimination results with the addition of expert quality control.

1.1 Company Description

SC&A has extensive UXO experience. The GeoScience Division specializes in the geophysical and information technology aspects of UXO characterization and remediation. SC&A's GeoScience Division has five geophysicists, four GIS specialists, and four computer engineers with significant, direct experience in the UXO application. We have worked on more than 20 UXO sites over the last four years and have worked extensively with Huntsville in developing new and innovative technical solutions to the UXO problems. We helped the Corps lead the way in several technical areas which now are common-place in the industry; we pushed ahead the concept of a geophysical proveout at Fort Monroe; we championed the use of the EM61 as a viable alternative to magnetometery in some cases; we helped develop the concept of a standardized GIS-based approach to UXO work now referred to as the OE-GIS; we developed the concept of a database approach to target analysis, now called the OE-Knowledge Base; and we have developed, and are currently populating, a web-database of UXO signatures for U.S Army Corps of Engineers. We continue to participate in, and support the Government on, "leading edge" UXO technologies, both as the Prime Contractor for the Knowledge Base effort and JPG4, and as a technology voice in the industry. SC&A is totally committed to this business, holds a Board of Director seat in the National Association or OE Contractors (NAOC), and is currently participating in or recently completed work at: Pole Mountain WY, Fort Greeley AK, and Fort Dix NJ, and Rocky Mountain Arsenal, CO, Savanna River, OH.

1.2 Project Team and Roles

SC&A brings a wealth of experience and expertise to the discrimination problem. Our seasoned staff has led the data processing effort for UXO detection for years. More recently, we have developed our own data collection systems and have proven these at UXO sites around the country.

Likewise, Foster Wheeler brings field logistical know-how and support personnel for field operations during the initial field tests as well as during the final field test.

1.3 Subcontractors and Team Members

<u>SC&A's in-house team consists of the following personnel:</u>

Dr. Jack Foley: As Vice President of SC&A and Director of the Geosciences Division, Dr. Foley is responsible for overall project management. As a nationally renowned expert in the field of geophysical detection of UXO, Dr. Foley has direct input into all aspects of SC&A's approach. Dr. Foley can be reached at the address and phone number on the cover page.

Dr. David Lieblich: As Chief Geophysicist of SC&A, Dr. Lieblich is responsible for designing and implementing field operations at JPG and leads the data processing effort.

Mr. Jason Chern: as programmer/analyst, Mr. Chern supports the data processing effort and develops new programs to accomplish the processing needs. In, addition he has participated in field operations as needed.

Mr. Rob Mehl: as staff geophysicist, Mr. Mehl supports the field effort as well as the data processing.

Ms. Laurie Loomis: as SC&A's lead contract person, Ms. Loomis is responsible for interpreting and complying with contracts.

Ms. Stacy McMahon: documentation, clerical, and financial tracking of contract.

Foster Wheeler Personnel:

Mr. Mike Pattaccia: as staff Geophysicist, Mr. Mcguire will aids data collection and field logistics at JPG.

Mr. Mike McGuire: as staff Geophysicist, Mr. Mcguire will aids data collection and field.

2.0 Demonstrated Technologies

2.1 Sensor System and Transport Mode

A Geometrics 858G magnetometer and a Geonics EM-61HH were the two types of instruments used. A non-magnetic cart carried six 858G cesium vapor sensors at a spacing of 2 feet and a Trimble Pathfinder Pro XRS GPS unit. A GPS Base station was set up over monument number 1 and recorded data for differential corrections. A diurnal magnetometer was set up to monitor time variations of the magnetic field. The EM-61HH unit, from Geonics, was used in the man portable (wheel mode) to collect EM data.

2.2 Recommended Applications and Technology Limitations

Magnetometers are passive sensors, they sense magnetic field variations caused by various sources. The EM61HH is an active sensor: it senses the decaying secondary magnetic field induced, by the system, in the subsurface. Both sensors are sensitive to noise that can be induced from the environment and the instrument. Environmental noise includes natural geologic variations as well as anthropogenically induced space variations of the local magnetic field. Certain natural and man-made time variations also induce noise. Magnetometers are useful for sensing ferrous objects to depths on the order of 10s of feet, depending upon size. The EM61HH is useful for sensing conductive metals to depths of about 3 feet.

2.3 Logistics Requirements

Area based magnetometery survey required two cart/equipment operators and one flagger. Flags marked the survey line boundaries. Grid based EM surveys required one equipment operator. Two ten foot measuring poles, compass and flags established grid boundaries and orientation.

2.4 Data Acquisition

Area based magnetometery data was collected using a non-magnetic cart. The effective sensor swath was 12 feet. Survey lines followed a north/south direction at average walking speeds. Grid based EM data was collected using a man portable EM61HH unit. Grid dimensions were 20×20 feet oriented north/south with the target in the center. Survey lines followed a star pattern starting at the southern midpoint heading north.

2.5 Data Processing and Interpretation

The basic data processing plans were described in the proposal and progress was presented presented (Foley and Lieblich, 1998). SC&A processed raw magnetic data by combining it with the GPS position data to obtain grids of each of the 5 survey areas. Magnetic data were corrected for the earth's field variations and filtered to remove localized noise. These data were gridded and signatures from each known target were extracted. The signature of each target was compared to the signatures in SC&A's signature database for identification. In addition, each target was fit with a dipole model of the magnetic field, to obtain model parameters. EM data were collected in individual target grids. These grids were compared to and EM database to obtain further target discrimination information. The results of these processes were then reviewed by an expert operator who made the final discrimination decision.

2.6 Quality Assurance

All data is quality controlled at different times during the collection and processing procedures. Raw magnetometery, EM and GPS data is QC'd after collection and download. GPS data is differentially corrected and checked for accuracy. Magnetometery data has dropouts/spikes removed and is checked for consistency. Grid files, for both data sets, are checked for target location accuracy relative to the given target locations and overall data quality.

3.0 Demonstration Results

3.1 Assumptions

3.2 Site-Specific Procedures

To accomplish a high resolution, multi-instrument, data collection efficiently SC&A applied a dual data collection approach that surveyed areas with magnetometry and local target grids with EM. These procedures are not restricted to JPG: they can be transferred to any site.

3.3 Problems Encountered

During data collection, there were some problems with local sensor dropouts: these were eliminated in the data processing. Local topography over targets, such as holes and uneven ground hampered the data collection, primarily on the local EM grids. Trees, primarily on the southeast corner of area 2 cause the GPS to lose its real time kinematic lock and the carrier phase. We found, however, that slower speeds approaching the trees and a lower GPS horizon eliminated this difficulty.

3.4 Discussion of Results

SC&A's discrimination results were obtained from a database comparison of extracted signatures supplemented by analytical modeling results and expert QC. Local degradation of pure target signatures, caused by geologic noise, proximity of other targets, and local instrument noise limited the discrimination results: quantitative comparison of target signatures with database signatures showed nonuniqueness of the resulting "best" match.

4.0 Digital Data

4.1 Raw Data

see attached disks with zip files.

4.2 Processed Data

See attached Classdta.xls

5.0 Conclusions

1. SC&A successfully teamed with Foster Wheeler to collect high resolution magnetometer and EM induction data at JPG4.

2. Collected data were processed and discriminated using SC&A's multi-instrument (magnetometer and EM induction) and multi-method (database, analytical modeling, and expert QC) approach software

6.0 References

Foley, J.E., and D.A. Lieblich, Advanced Analysis Applied to Conventional Geophysical Data at JPG4, proceedings from the UXO Forum, Anaheim, CA, May 5-7, 1998.

Development and Application of Technologies for the Discrimination and Classification of Buried Unexploded Ordnance-Phase IV

Pulsed Electromagnetic Induction (PEMI)
For UXO Discrimination

FINAL REPORT

by

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Applied Physics Laboratory
University of Washington

3 December 1998

Tetra Tech EM, Inc
Subcontract S0075-UXO-JPG4-006
Prime Contract N00174-96-C-0075

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JPG Phase IV Program

Pulsed Electromagnetic Induction (PEMI) For UXO Discrimination

FINAL REPORT

Peter Kaczkowski, Ph. D.
Applied Physics Laboratory
University of Washington

SUMMARY

The JPG IV Pulsed Electromagnetic Induction (PEMI) project conducted by the Applied Physics Laboratory, University of Washington, seeks to demonstrate the discrimination and classification capability of the PEMI technique using custom built equipment. This is the final report for the project, which began in November 1997. Work has included rebuilding the 1995 PEMI testbed to render it more suited to field operation. A new transmitter circuit and new receiver coils were designed and built, and a totally new laptop computer data acquisition system was developed for JPG IV. A new sensor platform which uses a moving transmitter and receiver was developed to provide faster field operation procedure. The current platform includes a simple system for short range automatic position sensing.

The self-test provided an opportunity to test our equipment and familiarize ourselves with the test site. The rainy weather hampered our progress somewhat as it made the field very muddy in those areas where targets had been emplaced. We also had a brand new hardware and software system to test and spent a lot of the time “debugging” the testbed. We ended up only measuring responses from a few buried targets and got the most useful data from sample ordnance and clutter that was not buried.

The field equipment was in much better shape for the demonstration phase, and we surveyed 106 of the 160 targets on the JPG grid, as well as all of the 8 accessible WES targets. We did have a few problems and breakdowns of the PEMI system, and in spite of the good weather were not able to survey all targets on site. The discrimination results are based solely on decay constant estimates; we did not have time to use spatial processing to aid in discrimination due to earlier problems with getting the PEMI system field ready. Furthermore, though the demo phase data appears to be of high quality, the self-test data is inadequate in providing a template of “known” responses with which to compare later results from “unknown” targets.

1. Administrative Introduction

a. Company Description

The Applied Physics Laboratory conducts a university-based program of fundamental research, technology development, engineering, and education emphasizing Navy applications of ocean science, ocean acoustics, and ocean engineering. The Applied Physics Laboratory was formed at the University of Washington in 1943 to bring university resources to bear on urgent WWII defense problems. Today it continues its mission of research, engineering, and education in partnership with the U.S. Navy. APL draws on its own special expertise and the traditional strengths of a major university to provide innovative and imaginative solutions to complex technical problems. About half of the Laboratory's program is devoted to exploratory and advanced development programs in electronics, signal and image processing,

guidance and control, underwater acoustics, sonar systems, marine corrosion, Arctic technology, transducer design, underwater test ranges, tactical oceanography, and antisubmarine warfare. The other half is committed to basic research in ocean physics, polar science, and acoustics.

b. Project Team

The APL team is composed of three primary personnel. The Chief Scientist is Dr. Peter Kaczkowski, who has worked in geophysical exploration and ocean and medical acoustics for many years using electromagnetic and acoustic remote sensing techniques. He has applied the relatively well known Time Domain Electromagnetic Method (TDEM) developed in geophysical prospecting (*Kaufman, 1978a and 1978b; Kaufman and Keller, 1983; McNeill, 1980*)) to the UXO detection problem (*Kaczkowski and Gill , 1996; Kaczkowski, 1998*), and provided the conceptual design for the PEMI system for UXO detection and discrimination. In developing new instrumentation specifically designed with the UXO problem in mind, Bob Drever (Principal Electrical Engineer) applied many years of experience designing and building oceanographic instruments to the electronic design and assembly of the PEMI sensor and data acquisition system. Mr. Drever also did the LabVIEW™ programming that controls the PEMI data acquisition. The mechanical design and construction was done by Mr. Fred Karig (Principal Mechanical Engineer) who has many years of experience developing and directing deployment of a wide variety of equipment for ocean engineering projects. Management of the project relies on APL and University of Washington support departments for accounting and contractual matters. There were no subcontractors used in our project.

2. Demonstrated Technologies

a. Sensor System and Transport Platform

i. Sensor platform

A new sensor platform was designed and constructed for this project. Figure 1 illustrates the concept in which a non-conductive and non-magnetic wheeled platform accommodates the transmitter and receiver coils, and is connected by a rigid tow bar to a second cart which supports the electronics and PC data acquisition system. The sensor package is comprised of the transmitter coil, two 3-axis receiver coil assemblies, a 3-axis magnetic compass and 2-axis electrolytic tilt sensor, and a pressure gauge used to measure the sensor platform’s elevation. The operator’s cart carries the notebook computer, the receiver signal conditioning electronics, the transmitter electronics, the positioning electronics, and the transmitter power battery pack. The entire testbed weighs about 150 lb., and is intended to be a method development testbed rather than a commercial prototype system. Nevertheless, it is totally battery powered and automated enough to make field data acquisition a reasonably efficient procedure.

ii. Computer controller and data acquisition system

UXO PEMI responses are such that required data rates are relatively slow. A capable multichannel data acquisition system has been assembled using a battery powered PC (DELL laptop) and a commercially available analog input/output card (National Instruments DAQCard-AI-16XE-50), and using equipment available to the project from other sources at APL. The system is controlled by software written in LabVIEW® (National Instruments).

The control of the digitizers is established within the data acquisition program which also controls firing the transmitter. The receiver signals are digitized for the entire pulse sequence of Figure 2, but are only stored to disk after extracting the two decay intervals, inverting the negative pulse, and summing to cancel any 60 Hz and offset noise. Typically, 10 to 30 such pulse sequences are averaged together to improve the PEMI signal to noise ratio before storing the result at a given station. The number of pulse sequences used

in forming the average is determined by prior examination of the random noise level at the station, but increasing the number beyond 100 is usually not very worthwhile.

iii. Integrated position sensing

Position sensing is done with respect to a local 15 x 15 meter zone, using a compass heading reading and electrical odometers for tracking in the horizontal plane, and a liquid level system for the relative elevation. The two odometers are made with 10 turn potentiometers geared to tensioned spools of light line. The lines are tied to two posts fixed in the earth, defining the local grid. Post-processing the odometer readings is required to convert the measured arc lengths to X-Y grid coordinates. Since the target locations were marked at JPG IV, most of the target surveys at were made in straight line fashion using only one odometer and assuming a straight path.

b. Recommended Applications and Technology Limitations

i. The PEMI method applied to the UXO problem

In general, the PEMI method (or TDEM — Time domain electromagnetic method — as it is known in geophysics) seems well suited to the UXO problem because of several factors:

- It is generally insensitive to earth medium properties, or in the worst case the response signal from the host earth can be rather simply modeled
- Targets of different size respond at substantially different time scales, providing opportunity for classification and discrimination
- The relatively low signal frequency bandwidth allows for inexpensive hardware and man portable configurations

The method is conceptually a natural extension of magnetometry to the quasi-static electromagnetic regime, and can be used at several levels of sophistication depending on the complexity of the environment and target variability, from passive magnetometric measurements to active-source multi-component transmitter and receiver combinations.

The PEMI method is limited in that it does require relatively small distances (on the order of meters) between the system and the target, whereas GPR and other wave based approaches can use a much greater standoff, in principle. Furthermore, studies of the performance of the method in very complex environments with many clutter objects of like size/weight to target UXO (such as realistic high use impact zones) have not been conducted, and thus have not demonstrated that the method will succeed under realistic conditions. Accidental detonation of ordnance due to electromagnetic current generation in fusing mechanisms has likewise not been adequately characterized and may pose another limitation.

ii. The APL-UW system's limitations

The PEMI method itself is much more general than any particular hardware/software system implementation. We chose to develop our own system precisely because we did not wish to handicap the potential of the PEMI approach during its evaluation stage by using off-the-shelf components that were not designed for the UXO application. Nevertheless, funding constraints forced many compromises in our system, the most important of which are listed below:

- The prototype sensor platform was barely adequate to do the field work under nearly ideal test conditions at the JPG test site. Small ruts and ground profile irregularities were a challenge for the two carts (and the operators who had to move them!).

- The system had a simple but accurate local position sensing system. A more sophisticated position tracking system would be far more convenient in a field operation.
- The data acquisition and processing software was being developed as the program progressed and needs further refinement to make post-processing efficient.

c. Logistics Requirements

For successful operation, the current version of the PEMI system requires:

- Shipment by land or air to a local warehouse (we used Indianapolis area facilities); 800 lbs.
- Mobilization to site via cargo van
- Assembly time of 8 hours; tear down takes about 4 hours.
- On site requirements include 120 AC power, and safe place to keep electronic gear (e.g. trailer)
- Field conditions should be relatively benign, with modest ruts and brush (as found at JPG IV demo).
- Operation is slowed but not prevented by rain, although a downpour, lightning, or high wind would halt data collection.
- PEMI data collection may interfere with Magnetometry, and might be hampered by other active systems.

d. Data Acquisition Procedure

At JPG IV, the data acquisition procedure was comprised of several repeated steps. For each target surveyed, a PEMI profile over the target location (as marked by the Government's stake and flag system) was measured. The profile extended from a distance of a few meters away where there was no obvious target response to just past the target response peak, or to a few meters past the target response zone into purely background response if it seemed helpful to do so. The precise profile spacing is not critical and was determined by directly observing the spatial rate of change of the response; each station location was accurately related to the rest of the profile using the sensor tracking system and was used in interpreting the data for location and orientation. Some targets were simply measured at one or two stations to get an estimate of their decay constant. When things were going smoothly, a single station could take as little as 30 seconds to measure, and a profile could be done in under five minutes.

Step 1. Move the sensor platform to within 3 meters of the target location, and line the cart up so that the sensor package would be pulled over the target.

Step 2. Place a stake another 3 meters away (precise distance not important) and in line with the profile, and tie the X-axis position sensor line to it.

Step 3. Enter new target ID number and other comments, and set number of pulses for best noise reduction (about 30 pulses).

Step 4. Collect first data point, and then pull the cart back about 50 cm to 1 m. Collect next data point, and so on until the response becomes evident.

Step 5. Reduce the profile axis spacing to capture spatial variations of response, especially near the peak. Verify that no saturation is occurring, and that signal to noise is adequate for target response characterization and adjust the number of pulses appropriately (usually only 10 pulses were used over the target itself).

Step 6. Complete the profile, and move the cart to the next location.

e. Data Processing and Interpretation Method

Each station data record is comprised of two files: a header file containing system settings, platform position and orientation, and preliminary target response information, and a data file containing the complete time series of each of the six coil voltages during the transmitter-off time (+ and – pulses summed, and 10 to 30 such sequences averaged). Each target survey data is stored in its own folder (directory), in turn stored in a folder for that day's work.

Processing begins by performing time series fits to an exponential decay model with noise, and a first estimate is made of the late-stage decay constant, the signal amplitude, and the noise level, for each of the six coils (field components), for each station, and for each target. A second pass through the entire data set is then made to refine these estimates. For each target, an estimate is made of the longest decay constant characterizing that target: this is an estimate because the decay constant must have been *reliably measured* and certified to be a reasonable value rather than a spurious result from the inversion.

In principle, these decay constants provide a target "signature" that can be compared to a library of responses from known targets. The self-test was partially intended to provide that library, but unfortunately the APL-UW PEMI system was not working properly until the last day and a half of the self-test phase. Furthermore, better advance planning on how to measure in-air responses of the UXO and clutter targets provided on site would have produced a more useful database. Nevertheless, the demonstration phase target responses are broadly classified by decay constant using the values measured during the self-test and prior work conducted by APL in 1995.

f. Quality Assurance — Confidence measures

In general, since no UXO decay constants were ever measured (by APL) to exceed 35 ms, we placed a cutoff of 40 ms on all responses and assert that any targets with decay constants greater than 40 ms are classified *not UXO*. We were not able to make useable measurements of the 20mm or 60mm UXO, and consequently did not assign a UXO class to anything with a time constant shorter than about 10 ms. The remainder of the objects were classified by handpicking the range in which they fell. Fortunately, there is a wide range between 13.5 ms (81 mm) and 31 ms (105 mm) in which no library data indicates UXO. Many target decay constants came in near 25 ms and were deemed non-UXO. The confidence measure was based on measured amplitude as well as how close to a class boundary the decay constant fell.

3. Demonstration Results

a. Planned Site Procedures

Daily preparations included battery charging (required physically disconnecting the electronics cart from the sensor cart and bringing it into the trailer where power supplies were used to charge the batteries overnight) and data transfer (required removing the laptop from the electronics cart and taking it back to the processing computer at the hotel). The targets were located using the flags on site, but we had planned to register the PEMI profile data with respect to the local grid by tying in to the grid corners (we did not do this for most targets — see below.)

b. Problems Encountered

The APL PEMI system required significant assembly time at the JPG site, all the more so since it was the first real field test for the evolving prototype platform. It took a day to assemble, and another day to get the sensors and data collection system really working. Further tests of noise levels on the actual site indicated that the gradiometer array was not necessary at this site and led to a few hours of reconfiguring. (60 Hz noise was much worse on the 80 acre site because of proximity to the road and power lines). The bulk and weight of the system was also a challenge from shipping to in-field operation, and further improvements could make the system far more portable. Sensor platform grid positioning was done using fixed stakes and lines, though after surveying a few targets it was clear that the benefit of tying in to the local grid did not warrant the extra time. The line based registration system would be much more

cumbersome to use in realistic UXO applications than an acoustic or GPS tracking system, for example, but is nevertheless workable.

c. Discussion of Results

The demonstration data is of good quality but was only processed using decay constant information. Little statistical processing of results was done, and there are no quantitative confidence measures presented. No spatial processing was done, and could have gone a long way to help determine how the spread of measured time constants for a given target was related to the geometry of the target, transmitter and receiver coils. Because noise is always part of the measurement, the data does not often extend far enough into the "late stage" to show a single consistent time constant for the decay. Nevertheless, a target model which represents the complex response using two (or three) perpendicular loops (an extension of the earlier APL UXO model) may be invertible with profile data collected with the 6 coil APL sensor.

4. Digital Data (processed data enclosed on diskettes)

5. Conclusions

The JPG IV Pulsed Electromagnetic Induction (PEMI) project conducted by the Applied Physics Laboratory, University of Washington, seeks to demonstrate the discrimination and classification capability of the PEMI technique using custom built equipment. This is the final report for the project, which began in November 1997. Work has included rebuilding the 1995 PEMI testbed to render it more suited to field operation. A new transmitter circuit and new receiver coils were designed and built, and a totally new laptop computer data acquisition system was developed for JPG IV. A new sensor platform which uses a moving transmitter and receiver was developed to provide faster field operation procedure. The current platform includes a simple system for short range automatic position sensing.

The self-test provided an opportunity to test our equipment and familiarize ourselves with the test site. The rainy weather hampered our progress somewhat as it made the field very muddy in those areas where targets had been emplaced. We also had a brand new hardware and software system to test and spent a lot of the time "debugging" the testbed. We ended up only measuring responses from a few buried targets and got the most useful data from sample ordnance and clutter that was not buried.

The field equipment was in much better shape for the demonstration phase, and we surveyed 106 of the 160 targets on the JPG grid, as well as all of the 8 accessible WES targets. We did have a few problems and breakdowns of the PEMI system, and in spite of the good weather were not able to survey all targets on site. The discrimination results are based solely on decay constant estimates; we did not have time to use spatial processing to aid in discrimination due to earlier problems with getting the PEMI system field ready. Furthermore, though the demo phase data appears to be of high quality, the self-test data is inadequate in providing a template of "known" responses with which to compare later results from "unknown" targets. A future discrimination capability test program should consider making this library database data collection and analysis phase using in-air targets a more substantial part of the program.

Results of processing the buried target responses with decays constants alone may be adequate to do discrimination in many cases, but is certainly less than can be done. Including spatial variation of the target's field and inverting for a model that includes several different decay constants is likely to be fruitful and possible with the kind of data collected over a profile of stations and the 6-coil sensor. This data is now available for future processing of this sort.

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PHASE IV CONTROLLED SITE
ADVANCED TECHNOLOGY DEMONSTRATION
JEFFERSON PROVING GROUNDS
MADISON, INDIANA

Prepared for: **Tetra Tech EM, Inc.**
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Date of Investigation: **August 24 through August 28, 1998**

Prepared by:

John J. Breznick, General Manager
NAEVA Geophysics, Inc.

Contents

1 INTRODUCTION

1.1 Company Description

NAEVA Geophysics Inc. is a small business concern established in 1993 as a subsidiary of its parent company, North American Exploration of Virginia, Inc. NAEVA offers over 34 years of experience in providing geophysical and geological services to over 200 governmental and private industry clients.

NAEVA Geophysics has trained, experienced crews with state of the art equipment servicing clients from two offices in Charlottesville, Virginia and Rockland County, New York. Quality geophysical services are provided using the following methods:

- magnetics
- downhole video camera
- seismic refraction and reflection
- utility location
- borehole logging
- electromagnetics
- ground penetrating radar (GPR)
- self potential
- resistivity
- borehole GPR

1.2 Project Team and Roles

The project team consisted of:

Personnel	Title	Role
John D. Allan	President	Interpretation
John J. Breznick	General Manager	Data Acquisition/Management
R. Preston Hawkins	Geologist	Data Acquisition/Data Processing
J. Douglas Lam	Geologist	Data Acquisition/Data Processing
Leif B. Riddervold	Environmental Scientist	Data Acquisition/Data Processing
Dr. G. Hunter Ware	Senior Geophysicist	Data Acquisition/Data Processing/Interpretation

1.3 Subcontractors

Dr. G. Hunter Ware was a subcontractor to NAEVA Geophysics for the project.

2 DEMONSTRATED TECHNOLOGIES

2.1 Sensor System and Transport Mode

NAEVA Geophysics surveyed 160 targets within the 16-hectare technology demonstration area using man-portable Scintrex Smartmag SM-4 total field magnetometers, Geonics EM-61 metal detectors and Geonics Protem 47D time domain electromagnetic (TDEM) instruments. We used a customized 2.5 m x 2.5 m transmitter coil and 1m² high frequency receiver coil for improved signal/noise ratio, in lieu of the usual EM61-3D coil arrangement.

The Scintrex Smartmag SM-4 system is based upon a very sensitive self-oscillating split-beam cesium vapor magnetometer. It measures the total magnetic field with a sensitivity of ± 0.01 nT (range 15,000 to 100,000 nT) at sample rates from 1 to 10 samples pr second. The SM-4 system includes a cesium sensor, associated electronics, carrying harness, ENVI control console, ENVIMAP operating

software, and rechargeable batteries.

The Geonics EM-61 is a time-domain electromagnetic instrument designed to detect shallow metallic objects with good spatial resolution. The system consists of two air-cored coils, each one meter in diameter, batteries and processing electronics, and a digital data recorder. Secondary voltages induced in both coils are measured in millivolts. The coils are arranged so that the larger coil (EM source and receiver) lies 40 cm below a second receiver coil. The instruments were operated in wheel mode with the exception of a few targets that were surveyed with the bottom coil on the ground.

The Geonics Protem 47D is a time-domain electromagnetic instrument which measures the decay of a time varying secondary magnetic field produced from currents induced in the subsurface. For the purpose of this demonstration, the instrument was used to measure the secondary magnetic fields produced from shallow buried metallic objects. The time decay of the induced eddy currents are measured at 20 geometrically spaced gates, over the time range 35 microseconds to 28 milliseconds. The Protem system included transmitter and receiver units, a 2.5 meter by 2.5 meter transmitter coil, and a high frequency receiver coil with amplifier.

The Geonics EM-61 (3D) operates under the same principles as the above described Protem system. In fact, the Protem transmitter and receiver units are common for each system. The major difference between the two systems are the transmitter and receiver coils, where the EM61 3D employs a smaller, 1 meter by 1meter transmitter coil and 3 orthogonal receiver coils. For limited use of the system, two of the three receiver coils may be removed, and data collected with one vertical component coil. The EM61 3D coils are mounted on wheels for ease of operations.

2.2 Recommended Applications and Technology Limitation

The first step in UXO characterization is the detection of the object. Detection depends upon rapid and complete coverage of an area with appropriate sensors, capable of responding to all objects of interest. For this purpose, magnetics and electromagnetics (i.e., cesium-vapor magnetometer, EM-61) have demonstrated satisfactory results yet have fallen short of being reliable, stand-alone UXO classifiers. Advancing a process from UXO detection to discrimination is difficult both in practice and in theory. The problem with most geophysical measurements is one of non-uniqueness. Many different objects produce the same or very similar signatures. Our research in the application of time domain electromagnetics, specifically for UXO discrimination, has shown encouraging results. Indications are that different ordnance types can be discriminated by their early, mid, and late time decay characteristics. Most critical to this process is the ability to gather data with a high signal-to-noise ratio, which can be limited by the particular size and burial depth of the UXO item.

2.3 Logistic Requirements

NAEVA Geophysics' geophysical ordnance characterization system can be employed with minimal logistical requirements. The instruments can be shipped through standard commercial services world-wide. The crew size is dependent on the area of investigation and can be as small as two persons. At this time it is necessary to investigate an area in two phases; first to detect and accurately locate potential UXO items and second, to reacquire the target locations for purposes of discrimination. It is expected that in the near future the system will be refined to collect all required measurements in a single pass.

2.4 Data Acquisition

Geophysical data were collected with a cesium vapor magnetometer, a EM-61, and a Protem 47D on all flagged targets within the demonstration area, in the allotted 40 hours time period. Because the target locations were identified and flagged prior to our arrival, the magnetometer and EM-61 were simply "profiled" directly over each target to obtain the desired information.

The Protem 47D was used to occupy five locations about each flagged target location. The first set of readings were collected centered over the flag and the remaining in a tight radius around the flag. This procedure was followed to help ensure that at least one data set was obtained when centered directly over the buried object. At each measurement station, the Protem was set for an integration time of eight and an accumulation of eight records. An integration time of four with four stacked records was found to be insufficient during our testing phase.

After completing the initial interrogation of all flagged targets within the allotted 40 hours the remaining time was spent re-interrogating some of the more difficult targets with the Protem using longer integration times and more records, and experimenting with the EM-61 3D.

2.5 Data Processing

The magnetic profiles were processed and analyzed using proprietary MAGFIT software. This software scans the theoretical anomalies of a very large number of magnetic dipole models (all locations, depths, orientations, and dipole moments of interest) over the field data, and identifies the best models using a "best least squares fit" criteria. EM-61 profiles were processed using Geonics DAT-61 software. Depth and signal strength determination by MAGFIT and DAT-61 were integrated. This allows an estimation of ordnance type but is not conclusive due to depth discrepancies and random remnant magnetism.

The Protem decay data were leveled (null corrected) using Geonics Protem software. The leveled decay curves were then smoothed using proprietary Matlab program. Decay curve shape characteristics were calculated using additional Matlab software and compared to a data base measured over JPG IV sample ordnance at various inclinations and depths. Finally, Protem characterizations were reconciled with EM-61 and magnetics predictions in order to arrive at final ordnance, non-ordnance declinations.

2.6 Quality Assurance

Data quality was ensured by: 1) experienced field personnel; 2) use of a base station magnetometer to eliminate the effects of diurnal drift; 3) instrument calibration as required; 4) repetition of select measurements for data comparison; and 5) daily review of geophysical data.

3 DEMONSTRATION RESULTS

3.1 Assumptions

It was assumed that the UXO items buried for the demonstration are of the same type as those provided as samples during the practice sessions, and that the buried targets are accurately located.

3.2 Site Specific Procedures

The use of the magnetometer and EM-61 instruments for this discrimination exercise was limited to data collection along discrete profiles directed specifically over flagged target locations. If target locations were not known, the instruments would be operated to provide full-site coverage for the detection and localization of those items. The information relevant to discrimination would then be extracted from the gridded data set. The use of the 2.5 x 2.5 m transmitter coil on the ground was dictated by the deeply emplaced targets.

3.3 Problems Encountered

At many of the target locations significant ground subsidence or disturbance exists, making it very difficult, if not impossible to maintain a consistent sensor elevation when passing over the target. Additionally, significant time was required to level the Protem coils in those areas.

A significant number of targets interrogated within the demonstration area are buried very close to or below their detection depth. It therefore becomes less reasonable to expect discrimination of these items that available detection technologies may not locate. If a satisfactory signal-to-noise ratio cannot be achieved, it then is impossible to accurately characterize the object.

3.4 Discussion of Results

With our integrated magnetic and electromagnetic surveys, we have selected 81 UXO targets and 60 non-UXO targets and designated 19 as unknown. Unknown items typically were to deep for their size, and signal/noise was too low for discrimination when responses of ordnance and non-ordnance overlap, we were conservative and selected ordnance. Our discrimination method is expected to be successful in recognizing ordnance, but will pass some non-ordnance with overlapping properties.

We could not identify 76mm (HEAT) projectiles, because no samples were provided. The only sample 81IL (iron) was broken, and missing tail and nose parts. Our method may mis-identify partial ordnance.

4 DIGITAL DATA

4.1 Raw Data

Raw data are provided digitally on a 3.5" diskette. It consists of all magnetometer, EM-61, and Protem data.

4.2 Processed Data

Processed data have been entered on the data entry diskette provided for this demonstration.

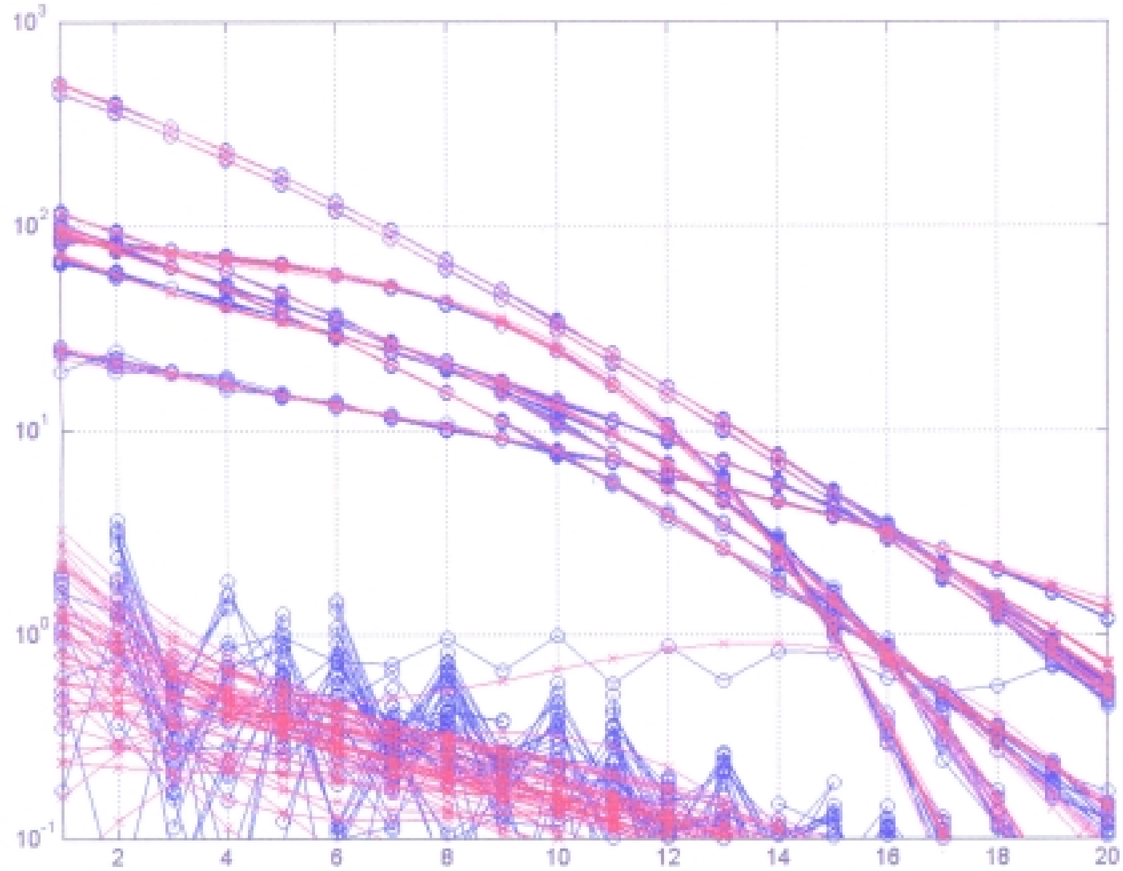
4.3 WES Area

Processed data for WES have been entered on a separate data entry spread sheet.

5 CONCLUSION

We believe that the integration of Protem, EM-61, and magnetic methods which we have employed are promising technologies for ordnance recognition and discrimination.

Further software development to integrate Protem and Mag - EM indicators is needed. Depth limitations may be overcome by increasing transmitter power, and decreasing transmitter - receiver coupling and receiver noise.



Example of Protem decay curves for buried metal objects and the background noise response at Jefferson Proving Grounds Phase IV Demonstration.

JPG 4 Demonstration
26-29 October 1998
Naval Research Lab

1.0 Introduction

The Chemistry Division of the Naval Research Lab demonstrated the Multi-sensor Towed Array Detection System, *MTADS*, at the Jefferson Proving Ground during the week of 26 October 1998. The program manager of the *MTADS* program is Dr. J. R. McDonald. His contact information is listed at the end of this report. Dr. McDonald was not on-site during the demonstration.

The demonstration team consisted of the following members listed with their affiliation and role:

Dr. H. H. Nelson, Naval Research Lab.	Deputy Program Manager
Mr. Richard Robertson, Hughes Associates	Project Manager
Mr. Larry Koppe, GeoCenters, Inc.	Vehicle Operator
Dr. Nagi Khadr, AETC, Inc.	Data Analyst

In addition, a local Temp Agency supplied two temporary workers to assist with navigation marking for the vehicle and general maintenance and support.

2.0 Demonstrated Technology

The *MTADS* is a multi-sensor, vehicular-towed array system. It incorporates both cesium vapor, full-field magnetometers and active, pulsed-induction sensors. The sensors are mounted as linear arrays on low-signature platforms that are towed over survey sites by an all-terrain vehicle. The position over ground is plotted using state-of-the-art, real time kinematic GPS receivers.

The magnetometers are a variant of the Geometrics 822 sensor designated the 822ROV. They have been selected for low heading error and minimum sensor-to-sensor variation. They are arranged in a 1.75 m linear array of 8 sensors horizontally spaced at 0.25 m. The array is towed 4.9 m behind the tow vehicle resulting in a N-S directional offset of ±5 nTesla. Total field data are collected at 50 Hz that results in an along-track sampling interval of 6 cm at our typical survey speed of 6 mph.

The pulsed induction system consists of an overlapping array of three modified Geonics EM-61 units. The modifications include changes such as increased transmit pulse repetition frequency to make the system compatible with vehicular towing and increased transmit power and analog gain to increase the sensitivity to small objects. The EM-61 array is towed 3.1m behind the tow vehicle. Data from this array are collected at 10 Hz, which results in a sampling interval of 15 cm along track.

Trimble 7400 MSi differential GPS receivers operating in the RTK mode are used for sensor position location. These units routinely provide positions good to 5 cm. The GPS positions are reported 5 times per second. The intermediate sensor positions are interpolated from these readings.

NRL, with support from AETC, has developed and integrated a data analysis system (DAS) to locate, identify, and characterize all military ordnance at its maximum probable self-burial depths. The DAS is efficient and simple to operate by relatively untrained personnel. The DAS uses resident, physics-based algorithms to execute target analyses either interactively or automatically.

The *MTADS* system is transported to a survey site in a rented tractor trailer combination. Logistics requirements include: presurveyed first order points for location of the GPS reference station; power for battery charging and computer operation; and storage and office space for the equipment. Power is supplied either by on-site service or a rented generator. Storage and office space is either rented or provided on-site. For the JPG demonstration, both these requirements were met on-site.

3.0 Demonstration Results

The four designated demonstration sites and the WES site were surveyed as single contiguous areas with the *MTADS* magnetometer system and the pulsed-induction system in two directions during the period 26 through 29 October 1998. Separate data were not acquired over any individual targets. Figure 1 shows the magnetometer system in operation at JPG. The magnetometer surveys of the five areas were completed on 26 October. The remaining three days were devoted to pulsed-induction surveys and an

Figure 1 - The *MTADS* magnetometer system in use at JPG.

attempt to acquire data on the test objects buried at JPG 4. A corresponding picture of the EM-61 system is shown in Figure 2. Data collected were checked on-site for completeness and proper sensor operation, and a preliminary analysis was performed to ensure that all targets were detected. Individual target analyses were carried out after the system returned to Washington.

Figure 2 - The EM-61 system in operation.

No assumptions or site-specific procedures were required for the *MTADS* survey. We did, however, encounter two specific problems during the course of the survey. We were denied the opportunity, afforded several other demonstrators, to survey the known portion of the 80-acre site. This survey would

have allowed us to collect representative signatures of the test objects emplaced and would have allowed better discrimination of the unknown objects. This information would have been extremely important given the convoluted, and in some cases silly, nature of the "non-ordnance" targets designed for use at this site.

The second problem was just this issue of choice of "non-ordnance." We are involved in several SERDP and ESTCP-funded programs designed to increase the classification capabilities of the *MTADS*. In each of these programs, we are focussing on shape as the chief discriminate. We have always maintained, and many in the field agree, that if we can discriminate cylindrical objects with an aspect ratio of 4 or 5 from plates and other essentially two-dimensional objects we will have advanced the state-of-the-art considerably. It is always been known both implicitly and explicitly that some pipe-shaped objects will have to be remediated along with intact UXO. The relatively large percentage of "non-ordnance targets" designed with the general size and shape of the intact ordnance seems intended less to measure the progress in discrimination in the field and more to ensure poor performance by all demonstrators.

4.0 Discussion of Results

The NRL proposal for this demonstration included 4 tasks. Tasks 2 and 3 involved analysis of the target signature data using fitting procedures being developed jointly by NRL and Blackhawk Geometrics under SERDP Program CU 1092/8 specifically designed to differentiate ordnance from OEW. Task 4 involved survey and analysis of the data for the WES 1-hectare site. Tasks 3 and 4 were not funded. The preliminary analyses provided for in Task 2, given the current state of the R&D development and the features of the non-ordnance targets at JPG IV, does not provide significant value over the baseline *MTADS* analysis algorithms for use at present.

As an alternative we have analyzed the target signatures using algorithms being developed for an ESTCP demonstration program, CU 199812, being jointly conducted with AETC. This approach strongly relies on fitting information acquired from EM survey data taken in orthogonal directions. This work is also in a preliminary state of development and the algorithms have not yet been tested on field data. This could have been done if we had been allowed access to the known portion of the JPG 80-acre site to calibrate on objects similar to those emplaced on the demonstration areas.

Without support, we also surveyed the WES 1-hectare site. Targets were analyzed using the same techniques as the remainder of the site, and the results are reported as part of this document.

5.0 **Digital Data**

The survey data (labeled as Raw Data Files) are provided on CD as they are too large for floppy or Zip disks. The information is provided as mapped data files, which are effectively sensor readings, located with coordinate positions. The readme.txt file explains their formatting and provide information necessary for their use.

The "Processed Data" are the target signature analyses in the required Excel Spreadsheet format. Per our telephone discussion, the target ranking (in column 2) assigns the lowest numbers to targets that we are the most confident are ordnance. We are confident that targets ranked152-160 are not ordnance. Targets ranked 74-79 had signal to noise values so low that we could not confidently fit them. They are included with the ordnance targets on the supposition that they must be dug because we cannot confidently classify them. Ranking values higher than 80, we deem more likely to be non-ordnance than ordnance. The classification of targets as projectile *vs* mortar is arbitrary because (with the exception of the 20 mm rounds) the ordnance types are completely interspersed; neither we or others can distinguish 76 mm projectiles from 81 mm mortars, etc.

In the comments line we have provided our estimation of the most likely ordnance description for targets that we classify as ordnance. Our size estimations overlap typically by one size in the list of included ordnance, *i.e.* our classification of a target as 81 mm mortar could well be either a 76 or 90 mm projectile.

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FINAL REPORT
PHASE IV CONTROLLED SITE
ADVANCED TECHNOLOGY DEMONSTRATION
US ARMY JEFFERSON PROVING GROUND
MADISON, INDIANA

for

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by

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Reviewed by:

____
Paul O'Donnell
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ADI Limited - Major Project Group

Authorised by:

____
Timothy Pippett
Project Manager
Alpha Geoscience Pty. Limited

Date: ______________________

This report and data has been prepared by ADI Limited and Alpha Geoscience Pty. Limited to document the survey and processing for the Phase IV Controlled Site Ground Advanced Technology Demonstration at Jefferson Proving Ground. This report and data may only be used for the purpose for which it was requested and may not be copied or used without the written consent of ADI Limited or Alpha Geoscience Pty. Limited.

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Copy ____ of 6

1. INTRODUCTION

ADI Limited (ADI) and Alpha Geoscience Pty. Limited were accepted to demonstrate technology for the interrogation and discrimination of buried items on the Jefferson Proving Ground 40 acre site. ADI are the prime contractor on this project.

1.1 Company Description

The company description is as follows:

ADI Limited - Major Projects Group 100 William Street, East Sydney, NSW. Australia.	Alpha Geoscience Pty. Limited Suite 7, 852 Princes Highway, Sutherland, NSW. 2232. Australia.

The Project Manager for this task was:

Mr. Timothy Pippett, Alpha Geoscience Pty. Limited, Suite 7, 852 Princes Highway, Sutherland, NSW. 2232. Australia. Phone: +61 (2) 9542 5266. Facsimile: +61 (2) 9542 5263. E-mail: tpippett @ ozemail.com.au

1.2 Project Team and Roles

The project team comprised of the following:

Name	Affiliation	Role
Timothy Pippett	Alpha Geoscience Pty. Limited	Project Manager, assisted in acquiring, processing and interpreting the magnetics and EM data.
Paul O'Donnell	ADI Limited - Major Projects Group	Acquired, processed and interpreted the magnetics and EM data.
Richard Yelf	Georadar Research Pty. Ltd.	Acquired, processed and interpreted the GPR data.
Stephan Heinze	Georadar Research Pty. Ltd.	Assisted in acquiring, processing and interpreting the GPR data.
Spencer Wilson	ADI Limited - Major Projects Group	Acquired EM data.
Erin Gorman	Georadar Research Pty. Ltd.	Assisted in acquiring the GPR data.
Michael Yelf	Georadar Research Pty. Ltd.	Assisted in acquiring the GPR data.

1.3 Sub-contractors

For this project, one sub-contractor was used to acquire, process and interpret the GPR data. The sub-contractor was Georadar Research Pty. Ltd. of 412 Eastbank Road, Coramba, Coffs Harbour, NSW. 2450. Australia. They were chosen for their expertise and experience in the GPR field, looking for discrete objects in the sub surface. Georadar Research provided all staff to undertake the GPR tasks.

2. DEMONSTRATED TECHNOLOGY

The following is a description of the geophysical equipment used on the ADI / Alpha Geoscience advanced technology demonstration:

2.1 AGS-1 Magnetometer Sensor System

The AGS-1 is a total field magnetometer from ASG Advanced Geophysical Systems GmbH. of Germany and is designed specifically for UXO location surveys. It is a complete package which includes data acquisition, processing, interpretation and documentation system for the location of ferrous contamination sources which have a UXO characteristic. The unit uses Caesium Vapour Magnetometer sensors (Geometrics Model G-822L), and these can be configured in one, two or four sensor configurations. For this technology demonstration, two sensors were used at a spacing of 0.5 meters thus allowing two lines of data to be collected concurrently. The unit was used in the man-pack configuration.

Distance down the line was controlled by a cotton odometer which was also used to trigger the magnetometer at the 0.1 cm. sampling interval, and cross line position was controlled by flags on the control lines. The magnetometer used distance base sampling. The resolution of the magnetometer on this survey was 0.01 nT. The sensor elevation for this survey was 0.6 meters.

The magnetometer survey was undertaken over the entire site of the buried targets rather than small grids over each individual target. This therefore provided an areal coverage of each site.

The software used to undertake the processing is run under Windows95, 98 or NT with no specific memory or speed requirements other than for Windows. The software used was AGSProc from ASG in Germany, it allows for the inputting, editing, filtering, display, interpretation, coordinate transformation and printer within the one package. The interpretation technique uses a simple dipole model to calculate the depth size, azimuth and orientation.

2.2 EM-61HH Time Domain Sensor System

The EM-61HH time domain sensor system (manufactured by Geonics Limited from Canada), with two time windows was used for this EM survey over the site. This unit records two time windows on the decay curve. The EM-61HH is a modified EM-61 using a figure of 8 coil system mounted approximately 20 cm. off the ground on a cart arrangement.

The EM-61HH data was collected using similar methodology as the magnetics, covering all the targets in each area. The EM system used a line spacing of 0.5 meters with a sample interval along line of 0.2 meters. The distance down line was provided by a wheel odometer.

The software used to undertake the processing of the EM data ran under Windows95, 98 and NT with no specific memory or speed requirements, other than for Windows. The software used was a propriety package from ADI to locate, edit and adjust the levels of the EM data before inputting into Geosoft Montaj for imaging, interpreting and printing.

2.3 SIR-10 Ground Penetrating Radar System

A SIR-10 Multi-channel GPR System manufactured by Geophysical Survey Systems Inc., USA, and modified by Georadar Research to suit this application, was used for the discrimination of the targets.

The GPR system provided real-time display of the 2-D radar sections collected along the ground. Generally radar profiles were collected across each target in two perpendicular directions. The antenna was pulled across the ground by personnel and the distance along each line was measured via an optical encoder wheel mounted on the antenna. All data was recorded digitally for subsequent processing and interpretation.

The antennas used for this project included a 900 MHz, 500 MHz, 400MHz and 200 MHz. central frequency. The radar antenna selection for each target was made based on the magnetic data interpreted depth to the center of the target.

To make sure that all targets were covered with GPR during the allotted timeframe, a second GPR unit, a SIR-2 system of similar specifications as the SIR-10, was used on the Thursday afternoon and Friday morning of the demonstration, covering a number of targets in Areas 1, 3 and 4.

The line spacing used over the targets was 15 cm's. either side of the center line which went directly over the market point of the target. The sampling interval along the radar lines was 1 cm.

Data was transferred to a PC computer for storage on a CD and subsequent processing. All data was viewed on the screen before and after migrating the radar data. Some data was imported into a 3D imaging package for viewing, however, as there were only generally three lines across a target in both directions, the 3D images were not an appropriate medium to view the radar data. All sections across a target were viewed and an visual interpretation made from the characteristics of the anomaly as to whether it was ordnance, non-ordnance, class, depth and diameter.

3. DEMONSTRATION RESULTS

3.1 Assumptions

Before mobilising to site, and determining the survey specifications, it was assumed that the non-ordnance targets would be items typically found in a live firing range. These items would be such things as fragments of ordnance items, buried fence wire and other items with an aspect ratio of less than 1:3. On viewing of the ordnance and non-ordnance items on site, this was not a correct assumption as ordnance items had an aspect ratio of similar to the ordnance items but they did have strong edges which were beneficial to the GPR data.

3.2 Site-specific Procedures

In regard to the magnetics and electro-magnetics, no site-specific procedures were adopted for the JPG site as against other ordnance sites with similar targets.

In regard to the GPR, the JPG site has always had a reputation of being a poor record of GPR successes and thus it was anticipated that lower frequencies would need to be used as against other less conductive sites. This was not necessarily the case on JPG for this demonstration as there has been considerable drying out of the ground over the last three to four months, with little rainfall occurring during this period thus reducing the moisture content in the ground and giving better GPR penetration. It was however, found that there was still moisture present in the soils which still caused attenuation and reduction of velocity from these areas.

3.3 Problems Encountered

There were two problems that were encountered during the undertaking of the demonstration, these were:

a. On the second day in Area 1, the EM operator carried a two way radio (which was switched on) on his person and although he did not use it to transmit, it generated enough EM field to reduce the quality of the EM data from the EM-61HH. This area was therefore resurveyed on the last day.

b. On the second day of the demonstration, an intermittent fault occurred in the AGS-1 magnetometer and this was traced to a broken wire on the cable from the data logger to the interface box. Once repaired, the magnetometer had no further difficulties.

3.4 Discussion of Results

The magnetics and electro-magnetics were interpreted over each target location with a depth, mass and orientation of the object being obtained from the magnetics data, and the electro-magnetic properties of the target being obtained from the EM-61HH. As both the ordnance and non-ordnance targets had a similar aspect ratio, no de from the magnetics and EM whether the item was ordnance or non-ordnance. Some preliminary estimations were made at this point and this was taken into account in the final analysis of the target type.

The GPR data resolution was extremely high and thus allowed the discrimination of items based on their shape and surface characteristics. The GPR was the predominant tool used for the discrimination of the items type. It should be noted that some of the non-ordnance items can be positively identified due to their distinct characteristics on the GPR records. This information has been included in the comments column of the data entry spreadsheet.

Comment has been made by Georadar Research in regard to the techniques for placement of the ordnance items and the difference what occur on "real world" sites. Using the radar technique, which is obtaining reflections of sub surface interfaces, the differential compaction, reflection off the sides of the trench and associated events, cause some difficulties in confirming the buried item, this would note occur in the "real world" due to the emplacement of the ordnance item. In future demonstrations, as much care as possible should be taken when emplacing items and backfilling to make sure that the hole used for emplacement will have the same characteristics as one which would be caused by an ordnance items penetrating the ground.

It should be noted that all targets could have been covered in the 40 hours by the one SIR-10 GPR system as the system had some time at the end to undertake fill-in areas.

4. DIGITAL DATA

4.1 Raw Data

Magnetics - all magnetics data collected was stored in the magnetometer and downloaded in ASCII form to the PC computer. This data was in a proprietary format, un-positioned except for control line information which was used to position the data on the site in the processing software. The fields that were recorded included header information, magnetometer values, time, control line marks and notes. The notes were used to indicate features on the ground such as where the sensors passed over the location marker.

The raw data provided on the CD is in the format specified, without the notes and with Easting and Northing giving position. No time was specified on the magnetics data.

Electro-magnetics - the electro-magnetics data was stored in the data-logger of the EM-61HH system and then downloaded to the PC computer. The data was in a proprietary format and included the EM values for both time windows, the control line marks and field notes.

The raw data provided on the CD is in the format specified, without the notes and with Easting and Northing giving position. Some times were specified on the electro-magnetics data.

Ground Penetrating Radar - the raw data from the SIR-10 system was stored on internal digital tape in a GSSI format (*.dzt). The data is in individual lines for each of the lines run across the target position. The format of the raw files transferred to the PC is in the same GSSI file format which is used for the archival of all the data.

4.2 Processed Data

The processed data supplied to the client was in the form of the required spreadsheet and was priorities from the "most likely to be UXO" at the top of the list, to "most unlikely to be UXO" at the bottom of the list. Comments have been added to items that we considered were positive identification based on the items displayed in the shed on site.

5. CONCLUSIONS

It can be concluded from the ADI / Alpha Geoscience demonstration that the magnetics and electro-magnetics techniques are suitable primarily for the location of targets when the aspect ratio of the targets is similar to ordnance. The GPR technique is a more suitable technology for the discrimination of the targets as to whether they are ordnance or non-ordnance.

Although the JPG site is not a particularly suitable site for GPR, good results were able to be obtained down to 2 meters on most targets, which is extremely encouraging for other ordnance contaminated sites where the ground conductivity are likely to be far less than at JPG.

With further development of the methodology for GPR acquisition including using multi-transducers and further development in making the software more specific to the discrimination task, the technology is amicable suitable to this task on ordnance ranges. From estimations undertaken by the team, a rate of approximately $ 50 per target could be obtained on a large ordnance contaminated site. This compares very favourably with the USAE cost per target to excavation of approximately $ 200. per item.

6. REFERENCES

The following reference material was used in the compiling of this report.

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Controlled Site Advanced Technology Demonstration Program Phase III - US Army Jefferson Proving Ground, Madison, Indiana, US Army Environmental Center, April 1997, Report No: SFIM-AEC-ET-CR-97011.

Geosoft UXO System - UXO Target Analysis for Magnetics and EM-61 Data (Version 1.0), Geosoft Incorporated, May 1996.

Instruction Manual EM-61HH, Geonics Limited, 1997.

Ref: FinalRept.doc
File: AG-009
Date: 13-Jul-00

APPENDIX D

The Real Problem – taken from the JPG Live Site Demonstration Area

Actual Ordnance Targets Taken Out of the Ground During the CEG Demonstration

Actual Ordnance Targets Taken Out of the Ground During the CEG Demonstration

Actual Ordnance Targets Taken Out of the Ground During the CEG Demonstration

Actual Ordnance Targets Taken Out of the Ground During the CEG Demonstration

Actual Ordnance Targets Taken Out of the Ground During the CEG Demonstration

Actual Ordnance Targets Taken Out of the Ground During the CEG Demonstration

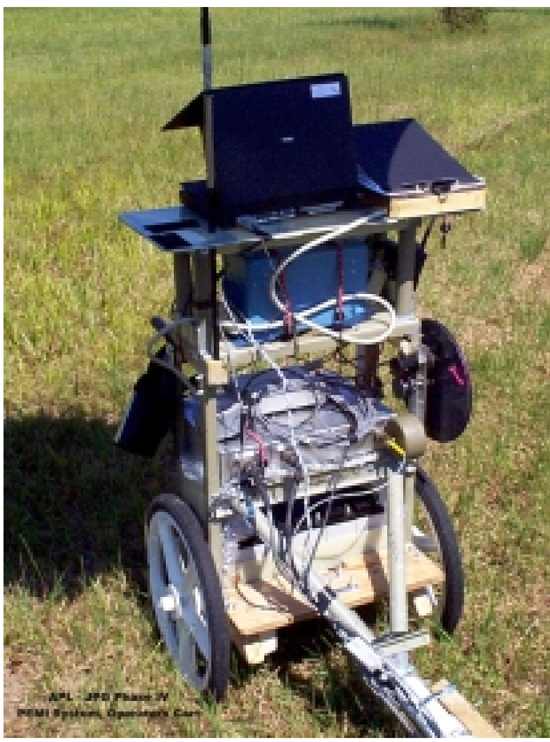
Hand Dig of Target #155 – 20mm HEI projectile

CEG Dig on Target # 88 – 4.2" mortar

CEG Dig on target #11 – 4.2” mortar

APPENDIX E

Applied Physics Laboratory



NAEVA Geophysics, Inc.

ENSCO, Inc.

Geophex, Ltd.


Geophex - JPG Phase IV
Grid Layout


Geophex - JPG Phase IV
GEM-3 Multifrequency EM

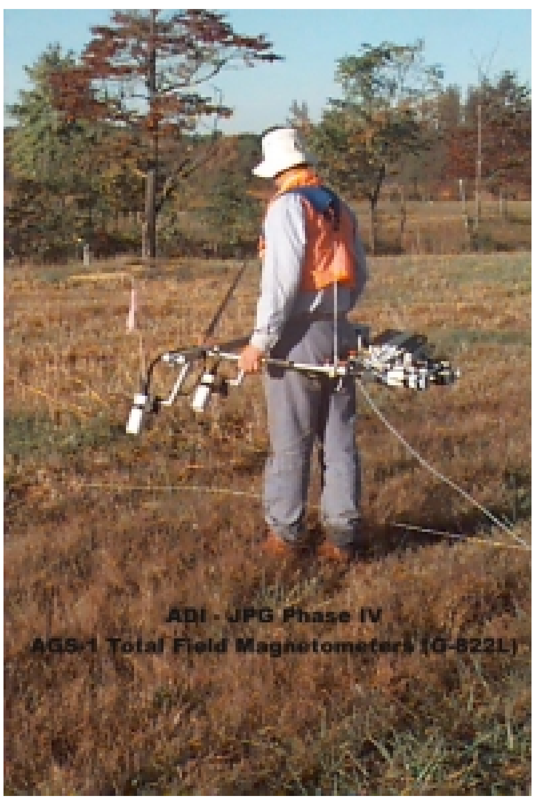

Geophex - JPG Phase IV
Geometrics G-858 Total Field Magnetometer


Geophex - JPG Phase IV
GEM-3 Test Jig

Battelle

Sanford, Cohen & Associates

ADI/Alpha Geoscience Pty. Limited



Geo-Centers, Inc.

Geophysical Technology Limited

Naval Research Laboratory

Concept Engineering Group

APPENDIX F

PHENOMENOLOGICAL INVESTIGATIONS AT THE JEFFERSON PROVING GROUND UXO TEST SITES

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Summary

The four demonstration phases at Jefferson Proving Ground (JPG) document some significant advances in unexploded ordnance (UXO) detection, discrimination, and identification capability. The JPG sites, originally thought to be simple sites for the UXO technology demonstrations in terms of geologic and cultural clutter backgrounds, have characteristics in some areas that can make UXO detection difficult. Detection of UXO must be accomplished in the presence of these backgrounds. There are inherent limitations on the detection capability of geophysical systems caused by the size and depth of burial of UXO (a given UXO may be too small and/or too deep to produce a detectable anomaly signature), and these limitations exist regardless of the geologic and clutter backgrounds. The geologic background further decreases UXO detectability by attenuating signatures, reducing physical property contrasts, and providing sources of localized anomalies. The cultural background or clutter decreases the reliability of UXO detection due to interference signals and false alarm anomalies caused by surface and buried cultural features.

Geophysical properties vary spatially and temporally at the JPG sites. Electrical and electromagnetic property variations as function of position, depth, and time are analyzed. Demonstrators have noted anomalous magnetic signatures at the site that have been attributed to soil property variations. These magnetic anomalies are investigated by acquiring in situ magnetic susceptibility measurements. A simple magnetic susceptibility model along a profile line is constructed from the measurements, and a total field magnetic anomaly is computed that is in qualitative agreement with the observations. The large observed and computed magnetic signatures illustrate how magnetic susceptibility variations in the shallow subsurface can complicate UXO detection. Soil types and properties and spatial and temporal variations in electrical conductivity and dielectric permittivity explain the past difficulty in detection of UXO with ground penetrating radar systems at the site. Conductivity and magnetic susceptibility variations also pose problems for electromagnetic induction systems in some areas of the sites.

Background

The JPG Phase IV UXO Technology Demonstrations included a science and technology (S&T) program, directed to answering outstanding questions and perceived deficiencies of the JPG program (Butler et al 1998a). The S&T program included

supplemental site characterization, establishment of a standardized 1-hectare site, assessments of prior JPG Phases, Phase III demonstrator self-assessments, monitoring Phase IV demonstrations, geophysical signature modeling for baseline targets, and phenomenological studies of spatial and temporal variation of environmental and geophysical parameters and associated effects on UXO detectability. This appendix surveys the phenomenological studies; complete results are found in Butler et al (1999).

Introduction to the Phenomenological Studies

In UXO detection and discrimination surveys, the geophysical sensor responses are a superposition of the signatures of (a) the host medium, (b) cultural sources and (c) the buried ordnance. Signatures due to the host medium and cultural sources constitute the background. Part of the response to the host medium will be due to materials (soil and rock) below the depth of burial of the UXO as well as surface topography. The host medium will generally be heterogeneous both vertically and horizontally on multiple size-scales (e.g., Butler 1975, Isaaks and Srivastava 1989, Sahimi 1995). Sometimes the host medium may contain rocks or tree roots or animal burrows comparable in size to the buried ordnance. In some cases the geophysical methods used for detection and discrimination of buried UXO may be relatively unaffected by the nature of the host medium, such as magnetic surveying for UXO buried in many typical soils. However, there are conditions where the nature of the host medium makes buried UXO detection problematic (e.g., Khadr et al. 1997), such as:

(a) high electrical conductivity soils that produce large electromagnetic (EM) induction responses and attenuate ground penetrating radar (GPR) signals after short distances of propagation;

(b) soils with high magnetic susceptibility or included rocks with high magnetic susceptibility;

(c) large rocks, tree roots, and animal burrows that produce GPR signatures similar to UXO;

(d) mixed, highly heterogeneous soils, with short spatial wavelength variability in electrical conductivity, dielectric permittivity, and/or magnetic susceptibility.

Cultural sources that contribute to sensor responses are: (1) objects ("clutter") on the surface or buried in the host medium, such as exploded ordnance debris and other metallic objects; (2) interference from EM transmitters/ emitters of various types. The geophysical signatures of buried ordnance depend on (a) size, shape, depth, orientation, composition, and physical properties of the ordnance, (b) physical properties of the host medium, and (c) inclination and declination of the local earth's magnetic field. Whether or not the geophysical signatures of buried ordnance are detectable depends on the magnitudes, spatial wavelengths, and other features of the signatures relative to the signatures of all other sources, i.e., the background. However, signatures of buried ordnance, that might be

“theoretically” detectable in a given setting, may not be detected in practice due to the details of the data acquisition process, e.g., inadequate sampling or measurement spacing.

Significant Environmental and Climatic Factors

The climate of JPG is described as moist, moderately humid, and cold in the winter and hot in the summer (Nickell 1985; McWilliams 1985). The primary environmental and climatic factors that can affect geophysical sensor response, are wind speed, vegetation, temperature, and rainfall. These data and other environmental parameters were acquired during the Phase IV demonstrations. The temporal variability of these factors are important for assessing or comparing performance of different geophysical systems and demonstrations at different times.

Wind speed. Wind speed and changes in speed and direction primarily affect gravity and seismic measurements, directly through flow against and around the sensor cases and indirectly through ground-coupling. Wind speed and direction at JPG are highly variable, but generally will not pose an instrument vibration problem except during thunderstorms and other severe weather. The prevailing winds are from the south, and the *average* wind speed is *highest* in the spring, about 5 m/s (11 mph). Gravity and seismic methods have not been used to date for UXO technology demonstrations at JPG.

Vegetation. Vegetation affects measurements with all of the geophysical methods. Larger trees and shrubs alter the uniformity of measurement grids and result in areas of no measurements. Variation in height of grasses will result in increased noise levels due to causing sensor elevation and orientation variations during surveys. Trees and tree roots can produce EM induction and GPR sensor responses that may be misinterpreted as anomalies caused by buried UXO (false alarms). Also, tree canopies can prevent the use of GPS for site navigation. The grass cover on the 40-acre site was kept mowed to a height of 10-20 cm during the demonstrations, particularly for Phases II to IV. Other vegetation on the 40-acre site is scattered and generally isolated, ranging from shrubs to mature trees. Generally the trees will interfere with measurements for a radius of 1 to 2 m. There are a few areas on the site where closely spaced trees or large trees with low growing limbs can interfere with measurements over an area with radius up to 5 m.

Temperature. Air and subsurface temperatures affects sensor response in three ways: (1) instrumental noise and drift for some sensors is sensitive to ambient temperatures; (2) changes in dimensions of components in a system can result in altered measurement geometry; (3) subsurface physical properties can vary with temperature. Subsurface physical property variation with temperature is generally small for temperatures above the freezing point, e.g., a 10 deg C temperature change will result in approximately a 20 percent change in electrical resistivity for electrolytic conduction in water saturated soil and rock. For relatively dry soil and rock, the change in electrical resistivity with temperature is quite small. For temperatures below the freezing point, the electrical resistivity is 1 to 2 orders of magnitude larger than at temperatures above the freezing point (Keller and Frischknecht 1970). The affects of temperature on instrument noise,

drift, and altered measurement geometry are completely sensor system dependent and require assessment for each system.

At JPG the average daily temperature range in winter is approximately -4 to 7 deg C (25 to 45 deg F), and in summer is approximately 18 to 30 deg C (65 to 87 deg F). Thus there is an average 10 to 12 deg C temperature change in any 24-hour period of the year and the temperature effect on resistivity for saturated soil conditions at JPG will typically be 20 percent or less in any 24-hour period. The effect of temperature change on resistivity between the extreme temperatures in summer and winter could be significant for saturated materials. However, the depth to “permanently saturated” materials in the area of the 40-acre site exceeds the subsurface depth extent of the annual and diurnal temperature changes. Significant periods of temperatures below freezing are not common, and the depth of freezing in soil is limited to a few centimeters.

Topography, Site Conditions, and Soil Series Maps

The topography of the JPG sites is gently rolling with minor drainage paths crossing the sites (Llopis et al 1998; Nickell 1985; McWilliams 1985). Cultural reshaping of the natural topography is minor, consisting of tire tracks, foot paths, small excavated soil mounds, and depressions resulting from ordnance burial activity associated with the demonstrations. After heavy rainfall, the tire tracks and other depressions fill with water, due to low permeability near-surface soils and are thus readily apparent. For the Phase I demonstrations, the sites were tilled prior to the technology demonstrations to conceal the ordnance burial sites, leaving a highly irregular small scale surface topography; the sites were not tilled for the subsequent phases.

For the 40-acre site, the maximum topographic variation is 8.8 m, with a well-developed drainage path from east to west and northwest across the northern part of the site (Figure 1). Topography and site conditions affect geophysical surveys in three ways, that are not necessarily interrelated: (1) rugged topography inhibits coverage with vehicular mounted sensor systems; (2) small scale topography introduces noise and “false alarm” anomalies; (3) topography correlates with soil type, soil moisture conditions, other soil properties which affect measurements, and vegetation. There are only minor vehicular access problems due directly to topography at the JPG sites; however, indirectly topography restricts vehicular system access to some areas of greater than normal density vegetation. The site tilling done for Phase I caused considerable survey problems for vehicular-mounted demonstration systems and created a major source of false alarms for the GPR systems. The noise levels for all survey systems in Phase I, both hand-held and vehicular-mounted, was increased due to varying sensor height and orientation relative to the surface and the buried ordnance.

Soil unit definitions and descriptions include typical surface slopes, thus it is not surprising that there should be some correlation between soil types and topography (Nickell 1985; McWilliams 1985). An overlay of topography and the general soils map for the 40-acre site (Llopis et al 1998) is given in Figure 2. Other correlations between topography and soil types and geophysical properties are noted in the following sections.

Soil Water Content

Soil water content is the major time-dependent subsurface variable that affects geophysical sensor response. Above the water table, soil water content is time-variable due to rainfall, infiltration, and evapotranspiration. Below the water table, soil and rock are completely saturated and have time-independent water content. The rate of infiltration is controlled by the vertical hydraulic conductivity of the soils. JPG soils have very low hydraulic conductivity, typically 10-7 cm/s, leading to ponding conditions in depressions after rainfall, including tire tracks and settlement depressions over ordnance burial locations (PRC Environmental Management, Inc. 1994; Nickell 1985; McWilliams 1985).

During prolonged dry periods, the ground surface becomes very hard, and during prolonged wet periods, the ground surface becomes very soft. During prolonged wet periods, the significantly increased soil water content zone will extend to depths of 0.5 m or more, but after moderate rainfalls the “nearly saturated” zone is confined to the upper few centimeters. An example of soil water content variation with depth is shown in Figure 3, for soil samples collected on 3 August 1997 (very dry conditions) and 29 April 1998 (very wet conditions) at grid location G7, approximately in the center of the 40-acre site. The numbers in parentheses by the nine sampling locations (triangles) in Figure 1 are weight-based water contents from August 1997 at 10-, 50-, and 100-cm sampling depths; mean water content for 10-cm depth for the nine locations is 13 ∀ 1 percent. For samples acquired at five locations in April 1998 at 10-cm depth, the mean water content is 33 ∀ 3 percent.

For JPG Phase IV, water contents were determined for 10-cm and 50-cm samples from three locations on the 40-acre site (K1, G7, C13; see Figure 1) each week during the extent of the demonstrations. These water content data are shown in Figure 4 as a function of time. The August 1997 conditions are comparable to the driest conditions encountered during the Phase IV demonstrations (15 September 1998). The April 1998 water contents for location G7, however, are higher than values observed for any of the three locations monitored during the Phase IV demonstrations. Thus the August 1997 and April 1998 site conditions effectively represent the extremes in shallow soil moisture during the period of investigations.

Soils Classifications

Failure of surface and airborne GPR systems at JPG is attributed to high ground electrical conductivity (leading to high GPR signal attenuation), scattering, false alarms associated with rocks in the soil, and rough surface conditions (Altshuler et al 1995; USAEC 1995, 1996, 1997). The high ground conductivity and signal attenuation are commonly and logically attributed to high clay content soils, exacerbated by high water contents at certain times (USAEC 1996). The fact that the water content of the shallow soils (samples from # 1.0-m depth) varies considerably during the year is documented in the previous section. Shallow JPG soils, collected at 21 locations, classify as sandy clay, silty clay, and clay, based on particle size distribution, and as low to high plasticity clays,

based on visual inspection (Llopis 1998; PRC Environmental Management, Inc. 1994). Engineering classification of the shallow JPG soils results in classification primarily as low plasticity clays. However, when plotted on a graph of engineering index parameters (Means and Parcher 1963; Cassagrande 1948), the JPG soils plot in a region of the space where soils can be either low plasticity clays or slightly plastic silts or very fine silty sands (see Figure 5; Llopis et al 1998). X-ray diffraction analyses of eight JPG soil samples reveal only trace amounts of clay minerals, with quartz being the predominant mineral (Llopis et al 1998). Thus the shallow JPG soils are very fine-grained, quartz silts and sands, and attenuation of GPR signals cannot be attributed to high clay content soils in the shallow subsurface. Results of field and laboratory investigations of past failures of GPR at the JPG sites are documented in Llopis et al (1998) and Arcone et al (1998).

Variability of Geophysical Properties

Geophysical site characterization. The site characterization surveys investigated the horizontal and vertical variability of the geophysical parameters that affect sensor performance—the electromagnetic properties as a function of frequency and water content. Electromagnetic properties were determined by electrical resistivity sounding, terrain electromagnetic conductivity, in situ complex dielectric permittivity measurements, GPR surveys, and laboratory testing. From in situ and laboratory permittivity measurements, conductivity, loss tangent, attenuation factor, and phase velocity are determined as functions of frequency and water content.

The magnetic susceptibility of the natural geologic materials was not expected to vary significantly over the sites. Thus the original site characterization did not include investigations addressing the spatial or temporal variability of the magnetic susceptibility. However, feedback from Phase II and III demonstrators indicates some significant areas of magnetic anomalies that are presumed to be caused by mineralogic variations in the soils. Field magnetic susceptibility measurements were subsequently made over two of the most significant geologic anomaly areas.

Electrical resistivity: Spatial and temporal variability considerations

Conductivity Maps. Electrical conductivity maps for the 40-acre site for dry (August 1997) and wet (April 1998) site conditions are shown in Figure 6. The maps indicate variability of soil and rock type and/or water content over the site. The EM system is a bistatic, frequency domain EM system that operates at 9.8 kHz. Depth of investigation of the system is nominally 4 to 5 m but is most strongly influenced by material in the upper 1 to 2 m. Each of the maps in Figure 6 illustrate the spatial variability of electrical conductivity for a given date, while comparing the two maps indicates the effects of different soil water content or intervening site disturbance on the conductivity distribution. As documented previously, the site conditions for the dates of the two maps in Figure 6 represent the “driest” (left map) and the “wettest” site conditions (right map) for the period August 1997 to November 1998 at the JPG 40-acre site. There is a general correlation between the conductivity distribution and soil types (see Figure 6). The correlations between soil type and conductivity are complicated by the facts that (a) soil

type correlates with topography and (b) generally the topography correlates with soil water content (higher elevation areas are typically dryer than lower elevation areas).

The general patterns of conductivity are similar in the two maps. Differences between the two maps relate to localized differences in soil water content or site disturbance, resulting from ponding of water in depressions and target burial activities between the times of the two maps. Simple statistical analyses of the values in the two conductivity maps are shown in Table 1. The *average (mean) and the standard deviation of the conductivity* increases only slightly (approximately 1 mS/m) from the dry to wet conditions map, although the *range of conductivity* values increases by a factor of 4 from the dry to wet conditions map.

Table 1. EM Terrain Conductivity Statistics — 40-Acre Site, Jefferson Proving Ground, IN

Statistic	Dyr (Aug. 1997)	Wet (Apr. 1998)
Minimum, mS/m	10.5	12.2
Maximum, mS/m	32.5	94.9
Average, mS,m	19.9	20.8
Standard Deviation, mS/m	3.6	4.8

Electrical resistivity monitoring. Vertical electrical resistivity soundings (VES) conducted on the 40- and 80-acre sites and the 1-hectare sites assess the vertical electrical resistivity variation. Detailed VES results and correlations with site geology are discussed by Llopis et al (1998). Generally the VES results indicate a 3- or 4-layer geoelectrical structure. For the 4-layer structure, simplified correlations with geology are: layer 1 — near surface, silty soils with high organic content and porosity; layer 2 — moist, silty materials; layer 3 — wet, higher clay-content materials; layer 4 — limestone. VES interpretations for grid location G7 for three dates are shown in Figure 7. The first two VES results (for August 1977 and October 1977) are for dry site conditions, while the third is for wet site conditions (April 1998). The major change from dry to wet site conditions is the dramatic decrease in layer 1 resistivity, from approximately 800 to 300 ohm-m.

Grid location G7, approximately at the center of the 40-acre, site served as a monitoring location for the Phase IV demonstrations. The major changes in the geoelectrical structure are in the resistivities and thicknesses of layers 1 and 2. The parameters for the upper two layers are well defined (resolved) in the inversions, while the resistivity and thickness of layer 3 are not well resolved (equivalence). A summary of the variation of the parameters of the interpreted geoelectrical sections for 7 VES is indicated in Table 2.

Table 2. Ranges and means of geoelectrical layer parameters for the G7 VES monitoring location for the period 18 August to 27 October 1998

Layer Parameter	Range	Mean
Layer 1 — Resistivity, ohm-m	450-880	655
Layer 1 — Thickness, m	0.3-0.6	0.5
Layer 2 — Resistivity, ohm-m	80-160	135
Layer 2 — Thickness, m	1.0-1.6	1.2
Layer 3 — Resistivity, ohm-m	25-38	30
Layer 3 — Thickness, m	2.6-3.5	3.1

Dielectric Permittivity: Spatial and Water Content Variability

The field and laboratory investigations of dielectric permittivity are thoroughly documented in Llopis et al (1998), for the frequency range 45 MHz to 4.045 GHz. Laboratory dielectric permittivity results are illustrated in Figure 8 for 200 MHz. Data plots for other frequencies are qualitatively similar. The plots in Figure 8, for all locations and all depths (surface to 1-m depth) on the 40- and 80-acre sites, are for the real and imaginary components of the relative complex dielectric permittivity and for the EM attenuation (dB/m) and conductivity (mho/m = 1000 mS/m) as a function of volumetric moisture content (percent). There is no obvious separation of values for samples from the 40- and 80-acre sites. For the 40-acre site, the real and imaginary components of the relative dielectric permittivity vary approximately linearly with volumetric moisture content between 10 and 40 percent, with a variation of less than ∀2 at any specific moisture content.

In addition to the laboratory dielectric permittivity measurements, two other field tests give insight to the spatial and frequency variation of the dielectric permittivity. Results of GPR surveys can be interpreted to give the *real part* of the complex relative dielectric permittivity, by conducting wide-angle reflection-refraction surveys and by analyses of diffraction hyperbolas. Llopis et al (1998) and Arcone et al (1998) present results of analyses of 70 hyperbolas in 300 MHz GPR profiles and 48 hyperbolas in 600 MHz GPR field profiles from the 40-acre site. Analyses of the results indicates no statistically significant difference in the mean and standard deviation of the real, relative dielectric permittivity values for the 300 and 600 MHz data (10.5 ∀ 4.2 versus 10.4 ∀ 3.5, respectively). Dielectric permittivity determined from GPR survey data are representative of volume-average values over the propagation paths that define the hyperbolic events. An in situ probe was also utilized to investigate spatial dielectric permittivity variability (Llopis et al 1998). The DICON probe (Miller, Malone and Blount 1992) makes a point (small volume) measurement of the complex dielectric permittivity at 60 MHz. Measurements were made at 10- and 50-cm depths at 25 locations on the 40-acre site (Figure 9). The permittivity values increase with depth everywhere.

Table 3 summarizes the measurements or determinations of real, relative dielectric permittivity. The laboratory measurements are for a moisture content of 25 percent, an appropriate moisture content for the time of the GPR surveys and DICON probe measurements. The values of relative dielectric permittivity are consistent, and there is a general trend of decreasing relative dielectric permittivity as frequency increases.

Table 3. 40-Acre Site Relative Dielectric Permittivities (Real Component) According to Test Type and Frequency for 25 percent soil moisture content

Test Type	Frequency, MHz	Relative Permittivity
Laboratory	100	13
	200	11
	495	11
	1,015	10
GPR	300	10.5
	600	10.4
DICON Probe	60	19.2

Magnetic Susceptibility: Spatial Variability

Magnetic susceptibility of near surface materials is not normally expected to vary significantly over short distances, particularly in a non-igneous terrain. It is not uncommon, however, for soils to have higher magnetic susceptibilities than the parent rocks due to selective sorting of heavy minerals (Burger 1992). Soil magnetic susceptibility can vary by factors of 2 to 3 over distances of tens of meters. Typical sedimentary rock susceptibilities average 5×10^{-4} (SI), while soil susceptibilities can be as high as 1 to 1.5×10^{-3} (SI). Commonly, the susceptibility variation of soils in an area (as portrayed in a histogram of values) will be unimodal with a rather narrow peak (Scollar et al 1990). Anomalously high or complex spatial variability of magnetic susceptibility were never suspected for the JPG sites.

During preparation for the JPG Phase IV demonstrations, the presence of significant, nonordnance-related anomalies of the magnetic field was revealed by some of the Phase II and III demonstrators. In addition to magnetic anomalies due to buried targets (ordnance and non-ordnance targets), the magnetic maps include other anomalies that can be attributed to cultural features and soil properties. An obvious cultural feature anomaly is the linear anomaly pattern that trends nearly due north-south along the western side of the 40-acre site that is caused by a fence. Another linear anomaly occurs between east-west grid lines 10 and 11 and is likely caused by the buried remnants of a fence. The longer spatial wavelength anomalies, many of which are subtle in expression, are presumably geologic in origin and likely from shallow sources. Two significant anomalous areas, that are not subtle, exist in the northeast and northwest quadrants of the site. These apparently anomalies follow the trends of drainage features across the 40-acre site.

Grid lines K and M and grid lines 4 and 6 approximately bound the large magnitude geologic anomaly feature in the northwest quadrant. More subtle expressions of the anomaly extend outside this area to the northeast and southwest, following the trends of drainage features. The magnetic anomaly map of this feature is shown in Figure 10, from the Naval Research Laboratory MTADS survey of the site during JPG Phase III (McDonald and Nelson 1999). Although the overall anomalous feature is complex, the most obvious aspect of the anomaly is a dipolar pattern, with a large magnitude negative band (~ -130 nT) to the south and a large magnitude positive band (~ + 115 nT) to the north.

The obvious approaches to investigation of the causes of geologic-origin magnetic anomalies are to measure laboratory and in situ values of magnetic susceptibility and to conduct laboratory mineralogical analyses of soil and rock samples. Two types of measurements were obtained in situ in the anomalous areas. A frequency domain EM system (Geonics EM38) was used to acquire terrain conductivity and magnetic susceptibility measurements (McNeill 1986) over the area bounded by grid lines K, M, 4, and 6 (61- $\times$ 61-m or 200- $\times$ 200-ft area.). Measurements were acquired approximately on a 6- $\times$ 2-m grid for terrain conductivity and on a 6- $\times$ 6-m grid for magnetic susceptibility. Magnetic susceptibility measurements with the EM38 are estimated to be a volume-averaged values for the upper 0.5 m of the subsurface, relative to the magnetic susceptibility of air. Magnetic susceptibility measurements were also acquired with a laboratory magnetic susceptibility system (MS2) fitted with a field measurement search coil (Bartington MS2 Magnetic Susceptibility System; Bartington Instruments Ltd. 1994) on a 6-m grid within the same area as the EM38 measurements, and additionally MS2 measurements were acquired along grid lines K and L at approximately 30-m intervals (100 ft). MS2 magnetic susceptibility measurements are volume-averaged values for the upper 15- to 20-cm of the subsurface, relative to the magnetic susceptibility of air (Dearing 1994). For the MS2 measurements, surface vegetation was scraped away and the search coil placed in intimate contact with the soil. Both the EM38 and the MS2 magnetic susceptibility measurements are real-component, volume magnetic susceptibilities in SI units.

Results of measurements to investigate the nature of the northwest quadrant geologic magnetic anomaly are presented in Figures 11 to 13. The EM38 operates at 14.6 kHz and has a nominal depth of investigation of 1.5 m (vertical dipole mode) for conductivity measurements (McNeill 1986). The conductivity values are low throughout the area (1 to ~ 17 mS/m), with the northern half of the area having an anomalously low average conductivity of ~ 2 to 3 mS/m. The same relative patterns of conductivity are evident in Figure 6, where the conductivities are for a nominal 5-m depth of investigation.

The EM38 magnetic susceptibility map is shown in Figure 12. Significant variations (an order of magnitude) in magnetic susceptibility occur over horizontal distances of 10 m or less. There are no obvious correlations to terrain conductivity (Figures 6 and 11). However, the correlation to the northwest quadrant total magnetic field anomaly (Figure 10) is evident. Figure 13 shows the MS2 magnetic susceptibility measurements along line

K; compared to the EM38 values where they overlap. The magnetic susceptibility along lines K and L both show a systematic decrease in values from approximately 6×10^{-4} (SI) in the north to approximately 1×10^{-4} (SI) in the south, with anomalous values in the area of the northwest quadrant magnetic anomaly. The EM38 and the MS2 values show the same trends in the anomalous area. Proceeding from south to north, a high-low-high pattern is noted. The EM38 values are higher in magnitude, indicating that magnetic susceptibility increases with depth in the anomalous area (at least in the upper 0.5 m of the subsurface).

Observations and Implications

The dominant environmental variable, affecting geophysical parameters and subsurface detection capability, is rainfall. Rainfall directly affects the soil water (moisture) content, which in turn plays a major role in determining the electrical resistivity (conductivity) and dielectric permittivity of subsurface materials. Due to the low hydraulic conductivity of near surface soils at JPG, rainfall tends to pond on the surface and infiltrate very slowly. Thus after small rainfall amounts, evaporation will dominate infiltration, particularly during the summer, and increased soil water contents will be limited to very shallow depths for short periods. Following large rainfall amounts, soil water contents are elevated to greater depths (0.5 m) and persist for longer periods (short and long periods are used as purely qualitative terms, since the present work did not quantify the effects). The average surface (~ 10 cm) natural soil water content during very dry site conditions is 13 percent (approximate range 11 to 15 percent), while the average surface water content during very wet site conditions is 33 percent (approximate range 28 to 38 percent). At a given location during dry site conditions, the water content will increase with depth (at least to 1-m depth); while during wet site conditions, the water content will decrease with depth. The water content measurements during Phase IV demonstrations indicate large fluctuations in surface water contents (as large as 20 percent), while the deeper (~ 50 cm) water content fluctuations are much smaller (5 to 7 percent).

The daily precipitation during the JPG Phase IV demonstrations is shown again in Figure 14, along with air and soil temperatures and the variation in parameters for the VES results. There are no obvious correlations between the VES parameters and temperature. There is a significant rainfall event (1.2 in. or 3 cm) on 20 September 1998, following a month with only trace amounts of rainfall. Following the rainfall event, the layer 1 thickness increases by approximately 0.4 m (with a corresponding decrease in layer 2 thickness) and the resistivity decreases from 620 ohm-m to 500 ohm-m. The resistivity of layer 1 varies from 450 to 750 ohm-m, with some fluctuation, over the course of the Phase IV demonstrations. The resistivity of layers 2 and 3 remain practically constant during the demonstrations.

Due to the depth of investigation (nominally 4 to 5 m) of the terrain conductivity maps in Figure 6, the affect of the shallow soil water content changes on conductivity are small. The major factor affecting the terrain conductivity is likely the clay layer present nearly everywhere beneath the 40- and 80-acre sites. Based on 25 VES results, the clay layer

beneath the 40-acre site varies from approximately 1.5- to 5-m in thickness, and the depth to top of the clay layer varies from approximately 0.3 m to 2 m (Llopis et al 1998). For example shallow depth to top of clay (determined from the VES results) is the cause of the high conductivity features centered approximately about locations D3 and K7, while depth to clay is apparently not the cause of the high conductivity area that extends from approximately I13 to A7.

The conductivity and dielectric permittivity variations for shallow depths (< 1.0 m) indicate significant changes as a function of water content. The laboratory properties at 200 MHz shown in Figure 8 show significant changes as a function of water content; this is illustrated in Table 4 for the measured water content extremes for dry- and wet-site conditions. The parameter ranges in Table 4 reflect the scatter in measurement data over the site (see Figure 8) at or near the indicated water contents.

Table 4. EM Parameters at 200 MHz for the Average Dry Site and Wet Site Conditions on the 40-Acre Site

Average Water Content, %	Real Component, Relative Dielectric Permittivity	Attenuation, dB/m	Conductivity, mS/m
Dry Site Conditions — 13	4-6	4-8	6-10
Wet Site Conditions — 33	17-19	15-25	40-60

The negative implications of the spatial and temporal variations of geophysical parameters over the 40-acre site for buried object detection are primarily for the magnetic methods and GPR. While the variations in electrical conductivity (resistivity) do have some implications for the EM induction methods, the impact on detectability considerations is minor for the type methods normally employed for UXO detection. For the time domain EM (TDEM) methods that are typically used, the measurement time gate is set such that the transient response from near-surface materials will decay to very small values, and the transient response from shallow-buried (< 2 to 3 m) metallic objects will dominate the superimposed measurement result (Butler et al 1998b). However, spatial variability in the conductivity will result in a small background noise component that will increase as the conductivity and its variability increase. Since the conductivity of metallic ordnance is of the order 10^7 S/m, only when the object is small and/or buried at depths > 2 to 3 m will the background geologic noise become a serious impediment to ordnance detection by TDEM (Barrow, Khadr, and Nelson 1996). The metallic ordnance to surrounding material conductivity contrast is typically 10^9 at JPG. The magnetic susceptibility variation over the 40-acre site poses a similar though potentially greater implication for UXO detection with TDEM methods than does conductivity (Das et al. 1990). The ferrous metallic ordnance to surrounding material *contrast* in relative magnetic susceptibility at JPG is as small as 10^5.

Even though the magnetic susceptibility contrast between ordnance and geologic materials at JPG is still quite large, detection of ordnance objects can become problematic

when “large volume” geologic magnetic susceptibility contrasts exist. The spatial distribution of magnetic susceptibility exhibited in Figures 12 and 13 is quite complex. It is possible, however, to qualitatively examine the magnetic field anomaly along a profile. A two-dimensional total field magnetic anomaly calculation is performed for line K (Figure 13). For the calculation, rectangular cross-section cylinders are used with approximate widths and magnetic susceptibility values from Figure 13, an assumed thickness of 1 m, and infinite length perpendicular to the profile. Results of the calculation, using a program based on the familiar line integral method (Talwani and Heirtzler 1964; Thorarinsson 1985), are shown in Figure 15. The maximum positive and negative values from the calculation are consistent with the measured values discussed previously. The abrupt changes in susceptibility in the model are responsible for the spiked appearance of the calculated anomaly. Including many more cylinders in the susceptibility model to simulate the transitional changes in susceptibility, would smooth the calculated anomaly. The complexity of the calculated anomaly and the horizontal gradients are consistent with the measured magnetic anomaly. Detection of ordnance with comparable or smaller magnetic signatures is problematic in this setting.

The most significant implications of geophysical parameters and their spatial and time variability for ordnance detection at JPG are for GPR. The conductivity maps in Figure 6, frequently good predictors of GPR “performance,” suggest variable GPR performance over the 40-acre site at a given time. A widely quoted criteria for qualitative prediction of GPR “performance” is based on conductivity: < 10 mS/m — excellent; 10 to 30 mS/m — marginal to good; > 30 mS/m — poor or problematic. The dry conditions map indicates conductivities ranging from 10 mS/m to > 30 mS/m. The data in Figure 6 and Table 4 suggest variable GPR performance as a function of environmental site conditions. For *dry conditions*, GPR performance in terms of depth of investigation should be fair to good for UXO detection nearly everywhere on the 40-acre site.

Two guidelines used for estimating depth of investigation d_{max} for GPR are (Annan and Cosway 1992; Annan and Chua 1992): $d_{max} < 30 / \alpha$ and $d_{max} < 35 / \sigma$, where σ is the EM attenuation in dB/m, σ is the conductivity in mS/m, and d_{max} is in m. These guidelines are based on experience with GPR in a variety of geologic settings and transmitter frequencies and the fact that most commercial GPR’s “can typically afford to have a maximum of 60 dB attenuation associated with conduction losses (Annan 1997).” For the maximum in the attenuation and conductivity ranges for dry site conditions in Table 4, d_{max} is 3.5 m for both rules-of-thumb. Depth predictions using the dry site condition conductivities from Figure 6 range from ~1 to 3.5 m. UXO detection with GPR for *dry site conditions* at JPG should be possible to depths of ~3 m in many areas. For the extreme wet site conditions (Table 4), the guidelines give estimates of depth of investigation ranging from 0.5 to 2 m, with $d_{max} < 1$ m, most likely. Since the Table 5 properties are for depths < 1 m, GPR detection of UXO greater than 1-m depth will be problematic for wet site conditions.

Table 5. Practical GPR Depths of Investigation at JPG for Selected Antenna Frequencies at Intermediate (Moist) Site Conditions

Center Frequency, MHz	Depth, m	Type Target	Comments
50	> 3.5 m	Geologic Interface	Depth of detection for localized high-contrast feature likely greater
100	> 2 m	Geologic Interface	See Above
200	> 1 m	Interface; Localized Feature	See Above
300	1 m 2-3 m	UXO Noise/Attenuation Limit	Well-defined UXO signatures; Arcone et al (1998)
600	< 0.5m < 1 m	UXO Noise/Attenuation Limit	High Attenuation at this Frequency

GPR considerations thus far do not specifically address the issue of frequency dependence of depth of investigation. GPR surveys conducted at JPG as part of the supplemental site characterization work (Arcone et al 1998; Llopis et al 1998) utilized different center frequency antennae. The references document the first reliably reported detection of UXO at JPG by GPR. The following tabulation lists depth of penetration achieved as a function of frequency for intermediate or moist site conditions.

Another important factor in terms of detection implications is the antenna beamwidth in the subsurface, which depends on dielectric permittivity. For example, the mean value of the real part of the relative dielectric permittivity, determined from an analysis of 118 GPR diffraction signatures acquired at JPG, is 10.4. For this permittivity value and commercial dipole antennas, the beamwidth perpendicular to the profile direction (in the plane of antenna polarization) is 22 degrees (Llopis et al 1998; Arcone et al 1998). This implies that a UXO would need to lie in or very close to the plane of the profile to insure detection, since out of plane reflections/diffractions will be highly attenuated. For the considerably higher permittivity values for some areas of the site, particularly for wet site conditions, the beamwidth becomes even smaller.

Conclusions

Implications of wet versus dry site conditions for GPR detection of buried ordnance at JPG are significant. Ordnance buried below the near-surface high water content zone, during wet site conditions, may *not* be detectable, while the same ordnance may be detectable during dry site conditions. Likewise for the TDEM method, the high water content near surface zone will have increased soil conductivity, resulting in a decreased conductivity contrast and a decreased signal to noise ratio. While the actual ordnance detection implications for TDEM are minor, cases where ordnance detection are predicted to be marginal under dry conditions, may be *undetectable* under wet site conditions. At locations where the clay layer is shallow and ordnance items are buried within the layer, detection by GPR becomes problematic for any site condition. Also, the electrical conductivity contrast is reduced for ordnance items buried in the clay layer, decreasing the

signal to noise ratio for TDEM surveys. Above the clay layer, the material is predominantly very fine-grained quartz, with only small amounts of clay minerals. High dielectric permittivity values at the site results in small GPR antennae beamwidths perpendicular to the survey line direction.

There is a significant spatial variation in near-surface magnetic susceptibility. The magnetic susceptibility of materials in the upper 0.5 m of the site can vary by an order of magnitude over horizontal distances of 2 to 3 m. The magnetic susceptibility variations produce magnetic anomalies that significantly interfere with detection of the magnetic anomalies of buried ordnance and also can reduce the magnetic susceptibility contrast, decreasing the signal to noise ratio for magnetic surveys. The most significant of these magnetic anomalies generally correlate spatially with the major drainage features of the site.

Examination of high-resolution, high-accuracy total magnetic field anomaly maps of the 40-acre site, reveals that the magnetic background (noise levels) areas of the 40-acre site vary from “quiet” (< ∀ 5 nT) to noisy (~ ∀ 20 nT). The predicted total magnetic field anomalies for the Phase II and III baseline ordnance items indicates the minimum peak positive anomaly magnitude for Phase III is 18 nT, while some Phase II baseline ordnance targets have anomaly values < 10 nT (Butler et al 1999). For the magnetically quiet areas of the site, only some of the Phase II baseline ordnance targets are difficult to detect. For magnetically noisy areas of the site, however, a small number of Phase III ordnance targets and a significant number of Phase II targets become difficult to detect. Relationship of the Phase IV baseline ordnance set to Phases II and III is discussed in Butler et al. (1999).

EM61 TDEM maps indicate considerable areas with background noise levels < ∀ 2 mV, although some areas have noise levels ~ ∀ 5–10 mV. While only a small number of Phase III ordnance targets are difficult to detect with an EM61-type TDEM system, a significantly larger number of Phase II targets could be difficult to detect, depending on the burial location at the site (Butler et al 1999).

The results documented here indicate the need to evaluate the results of UXO detection surveys based on site-specific criteria. That is, the probability of detection and false alarm rates can vary considerably over a survey area based on site specific geologic and soil conditions. Selection of appropriate geophysical survey methods should be guided by a priori assessment of geology, soil, and geophysical parameter variations. Geophysical signature modeling of expected ordnance types and depths should be conducted, with site-specific signal to noise considerations, to guide survey planning. Likewise, assessment of the results of geophysical surveys for UXO detection should be performed with cognizance of the site-specific conditions.

Acknowledgment

The authors appreciate the assistance of Drs. Nagi Khadr and Bruce Barrow, AETC, Inc., and Drs. Herbert Nelson and James McDonald, Naval Research Laboratory (NRL), in this

work. NRL provided JPG geophysical survey data, and AETC assisted with specialized presentations of the data.

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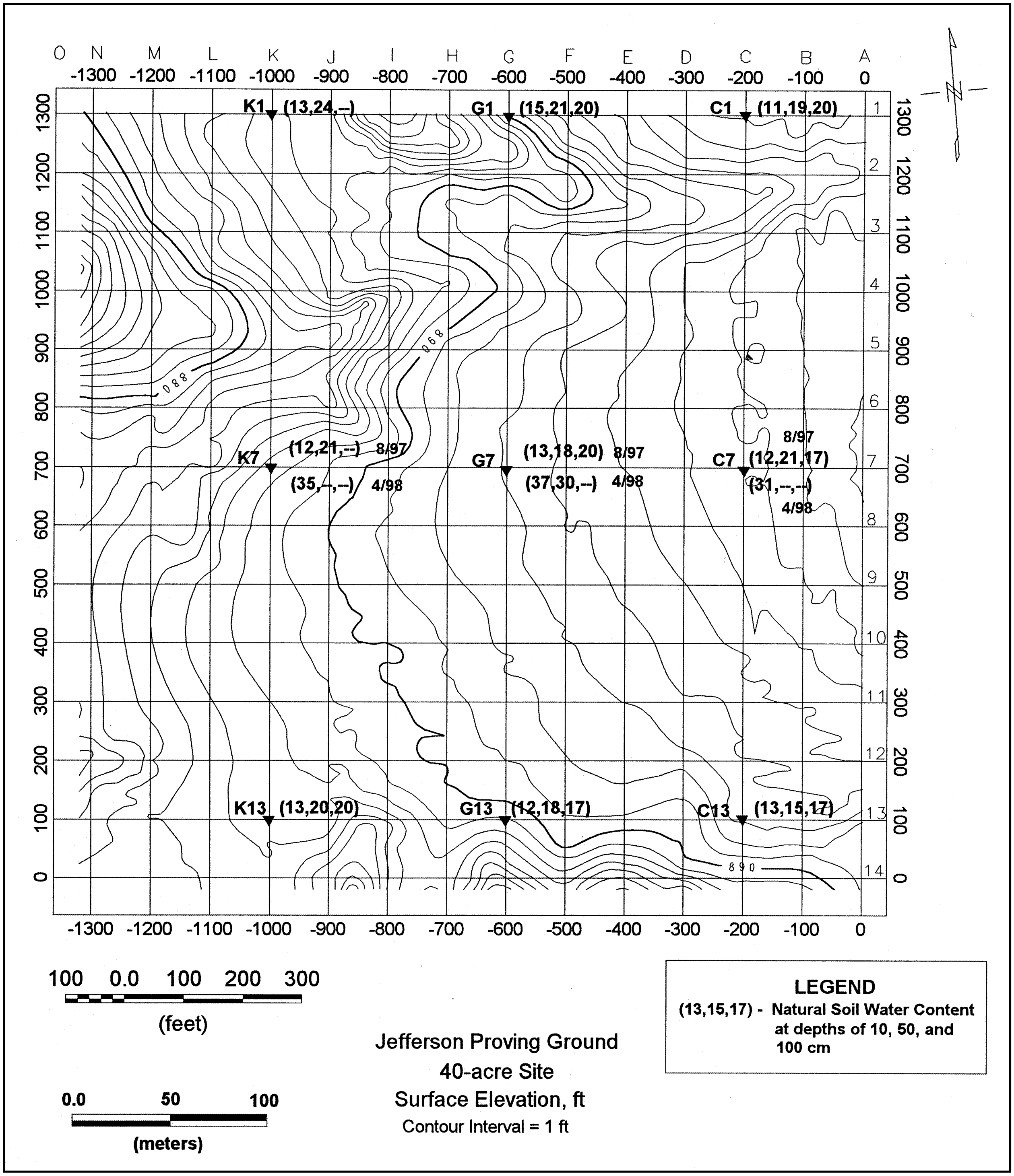

Figure 1. JPG 40-acre site map, showing nine locations where water contents were determined for 10-, 50-, and 100-cm depths for dry site conditions (8/97) and three sites where water contents were determined for wet site conditions (4/98)

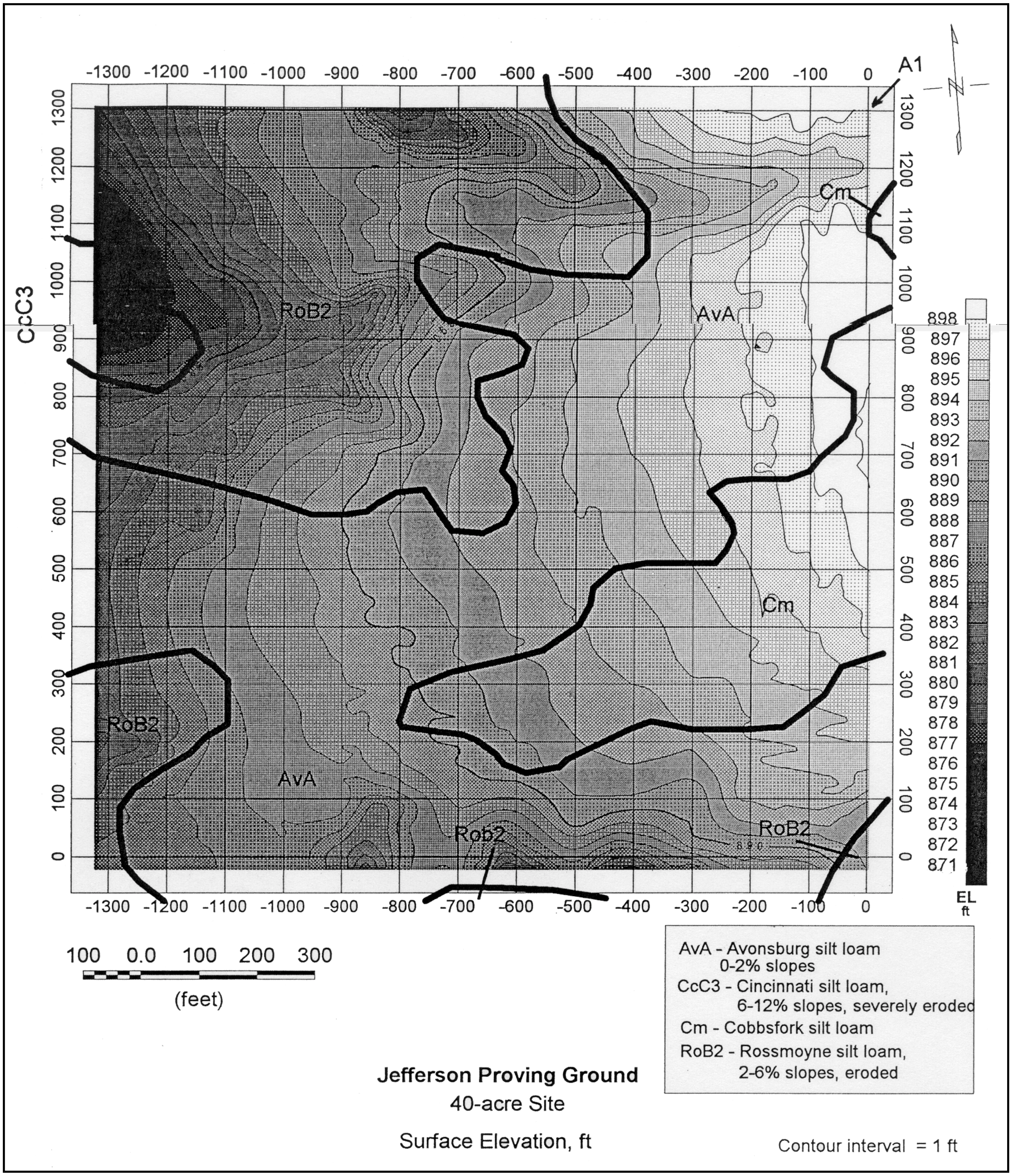

Figure 2. JPG 40-acre site: soild map superimposed on topography

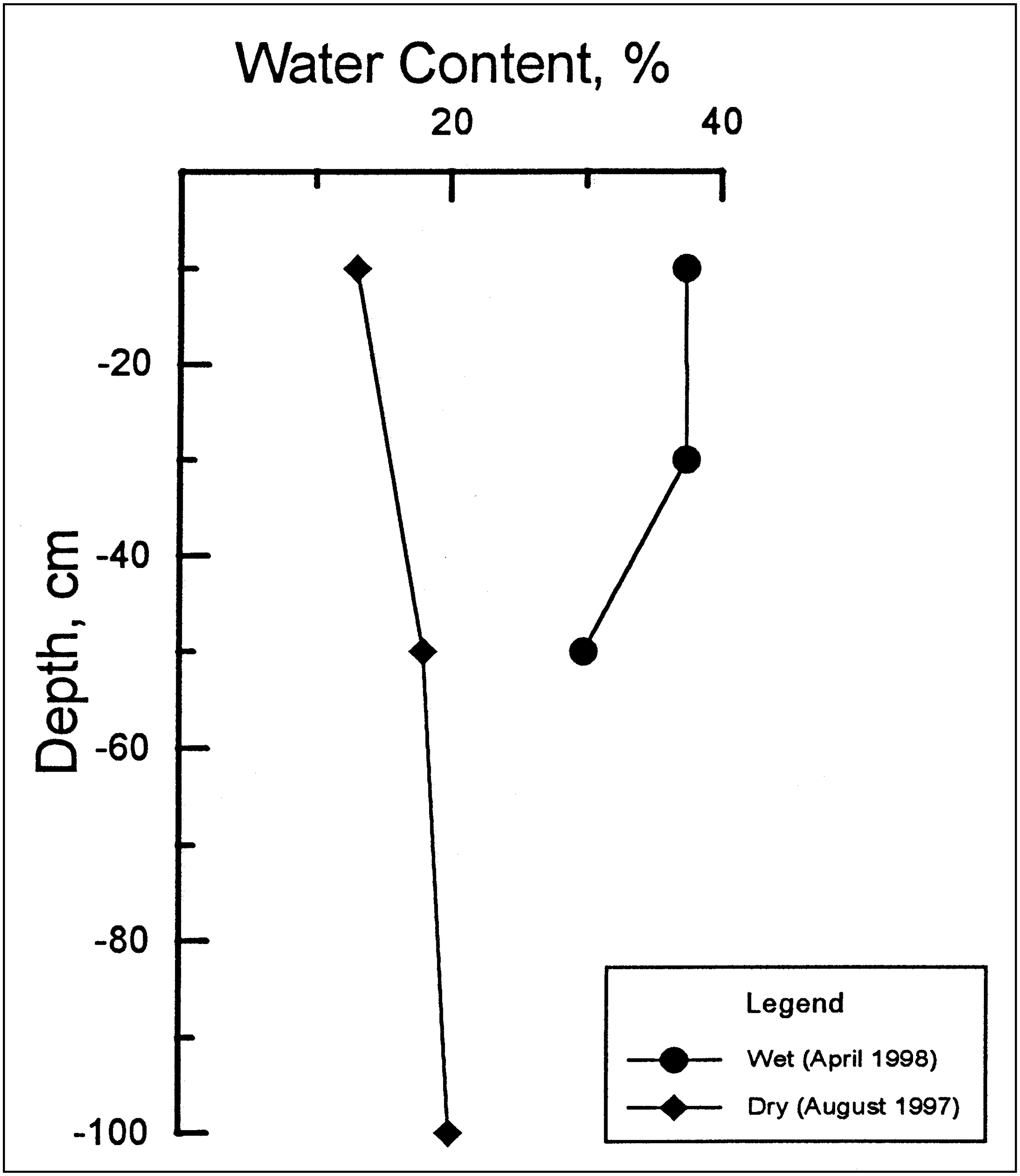

Figure 3. Variation of soil water content with depth for wet and dry site conditions at location G7, 40-acre site

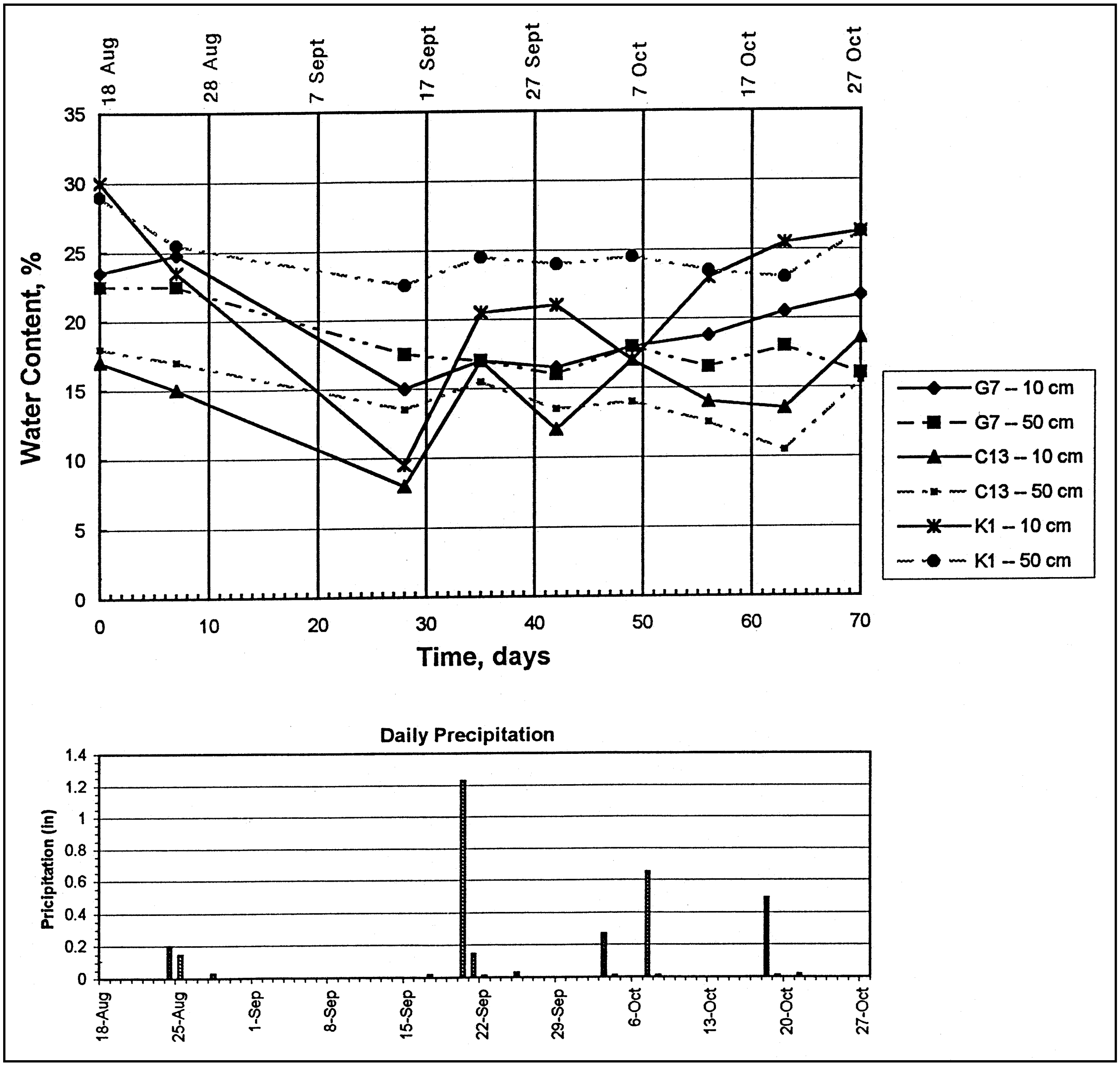

Figure 4. Natural water contents, for two depths and three locations, and precipitation during JPG Phase IV demonstrations

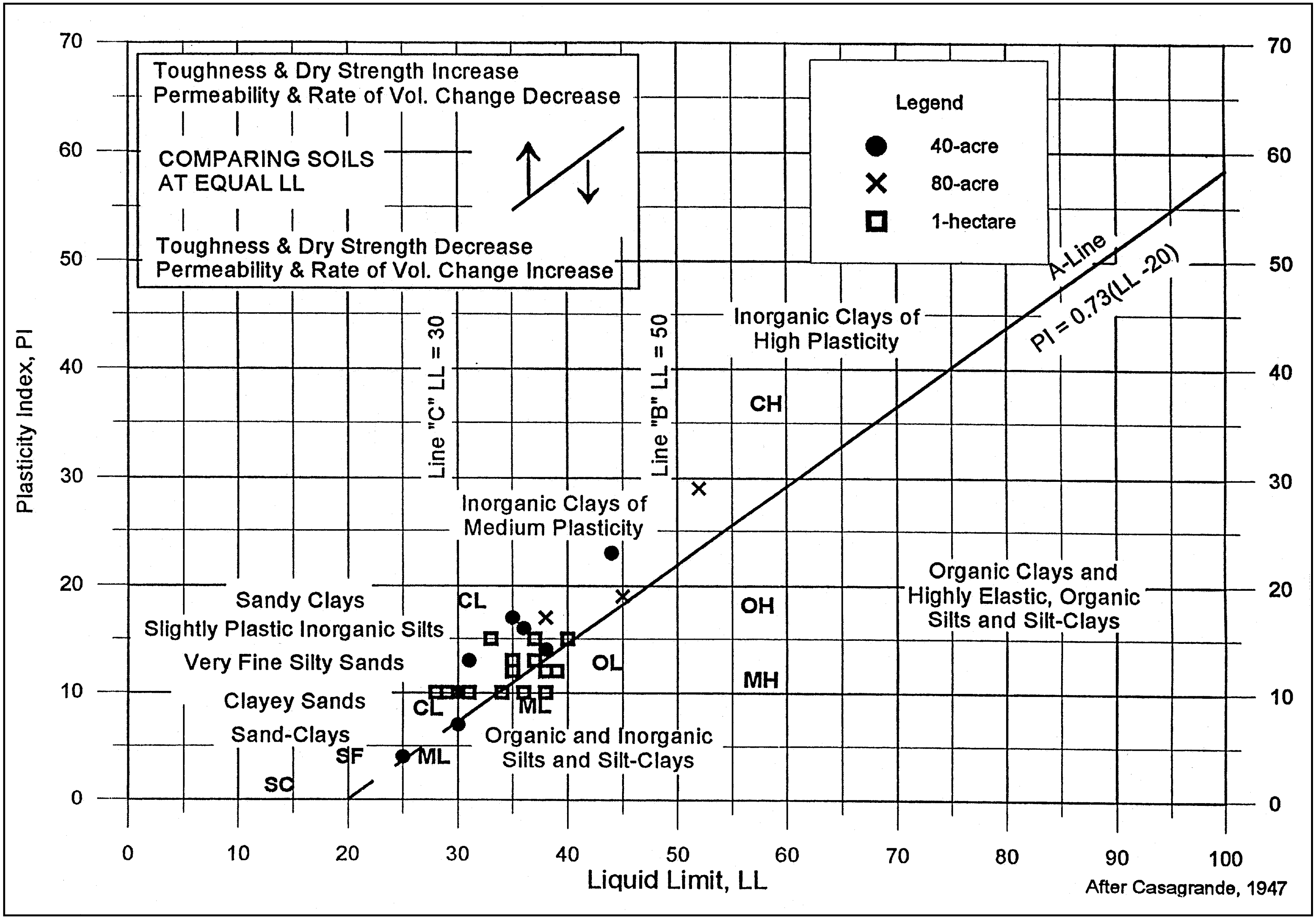

Figure 5. Soil index parameter classification chart (e.g., see Means and Parcher 1963) and JPG soils analysis results

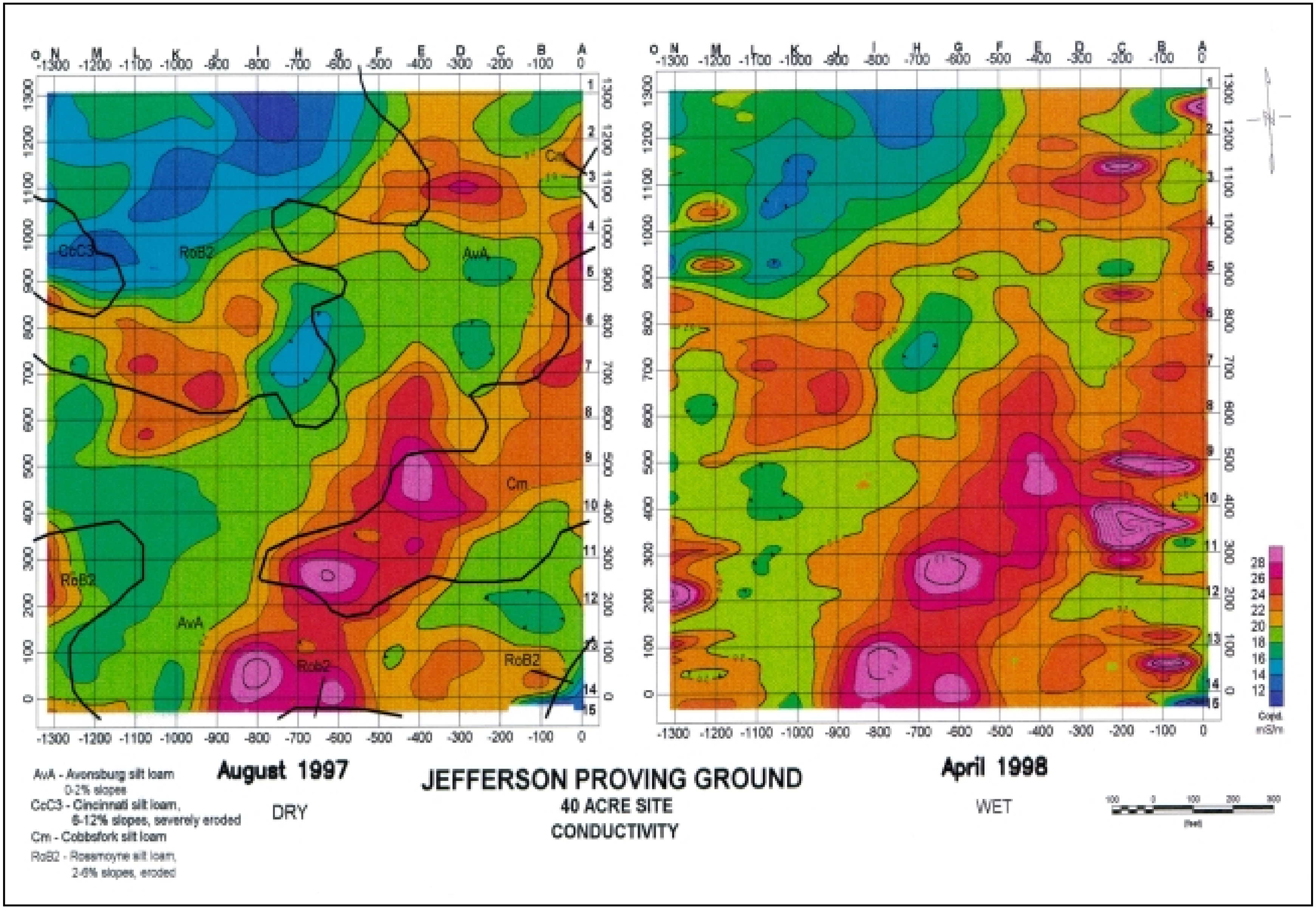

Figure 6. Electromagnetic terrain conductivity map for 40-acre site during dry (left) and wet (right) site conditions; determined with Geonics EM-31 (frequency domain EM induction system, 9.8 kHz)

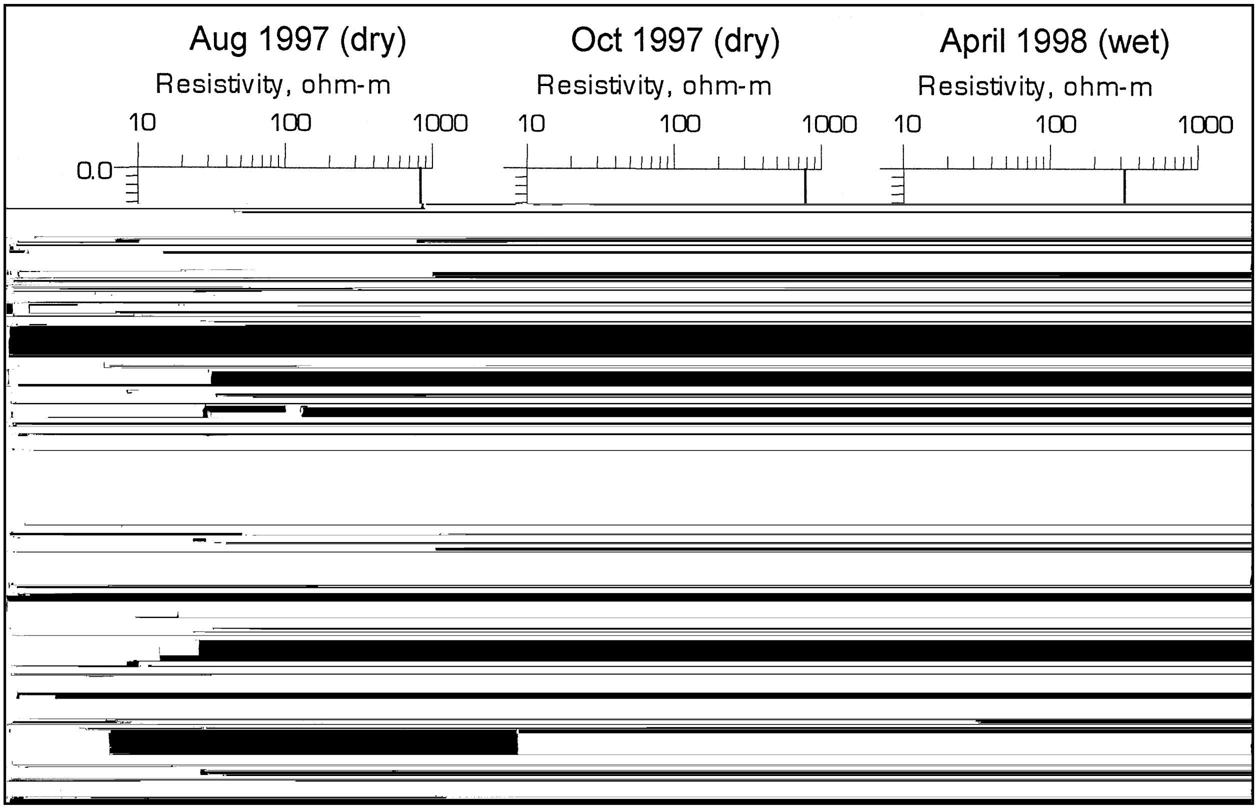

Figure 7. Electrical resistivity sounding interpretations for three dates at Location G7, 40-acre site

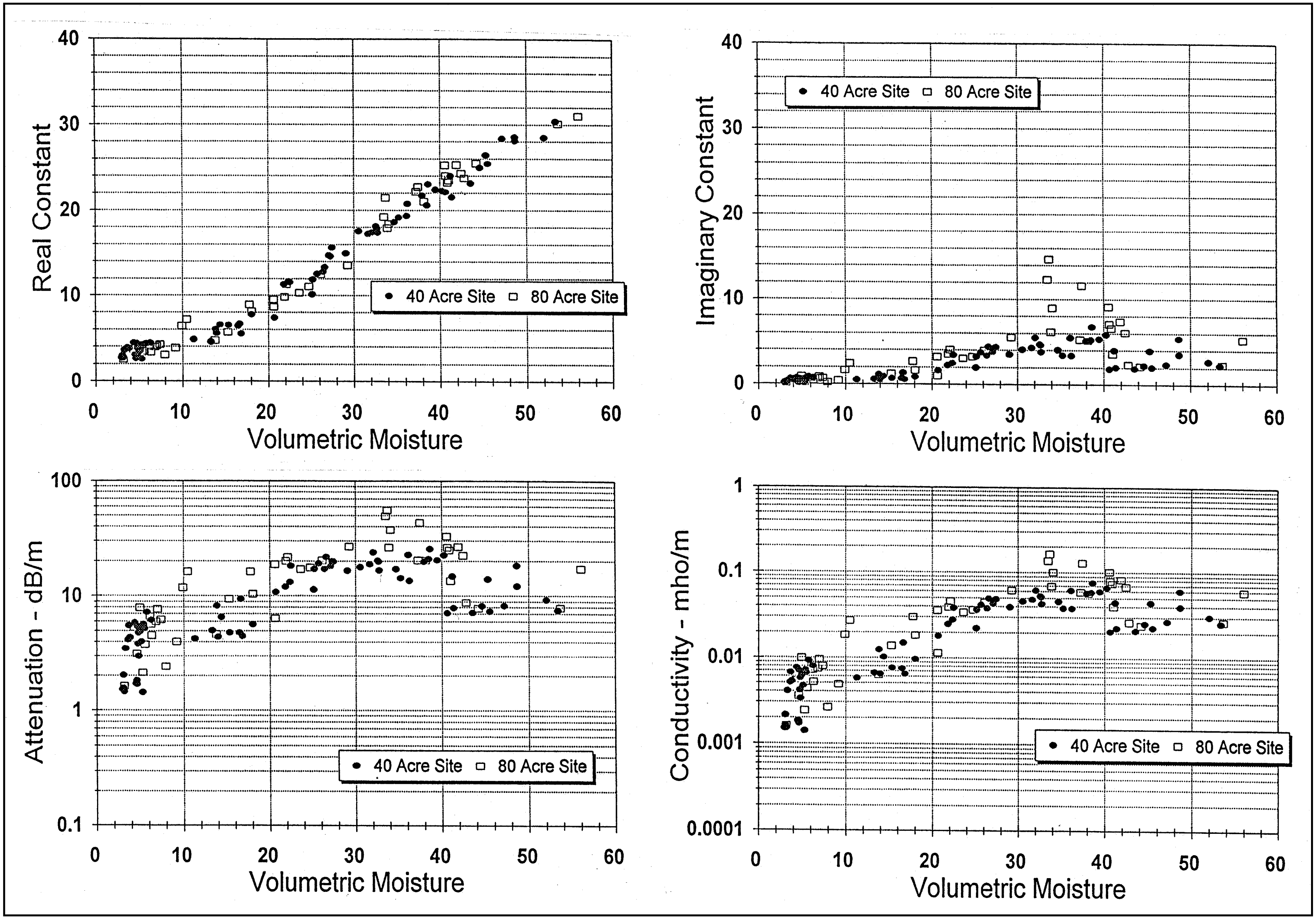

Figure 8. Example of laboratory electromagnetic properties measurements for shallow JPG soils at 200 MHz as a function of volumetric moisture content (Llopis et al 1998)

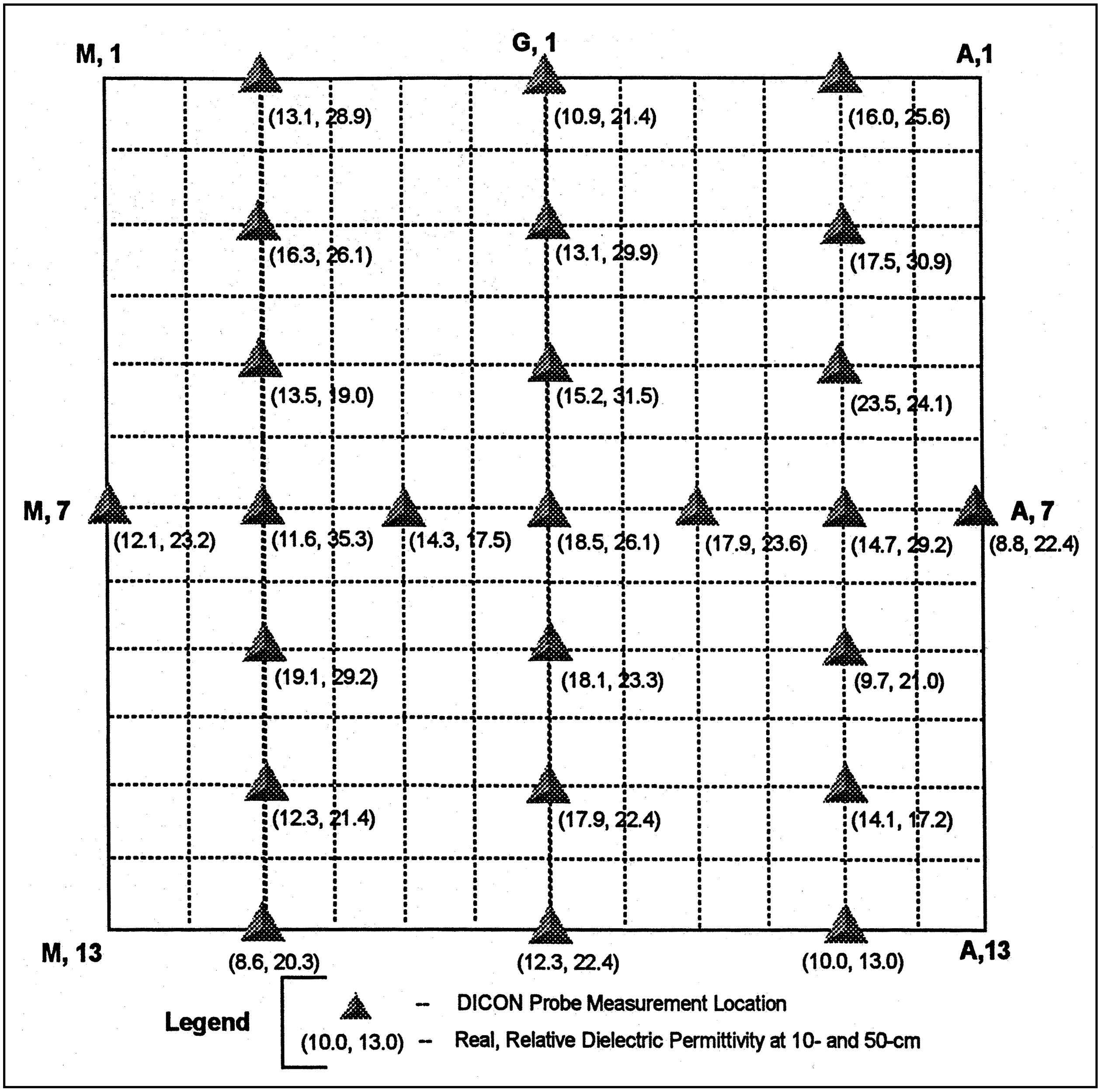

Figure 9. DICON probe measurements of the real component of the complex dielectric permittivity at 10- and 50-cm depths at the 40-acre site

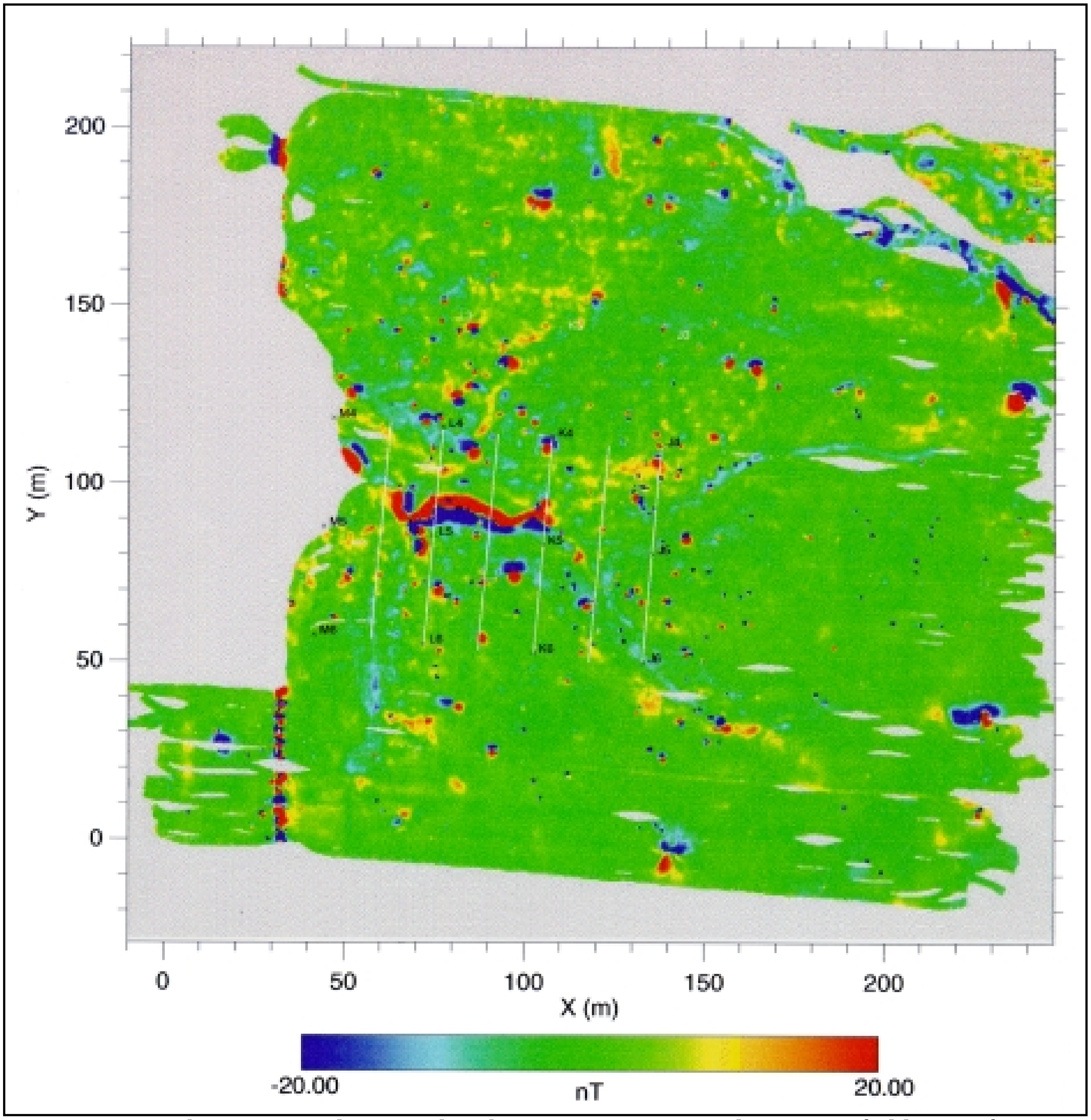

Figure 10. Phase III Naval Research Laboratory MTADS total magnetic field map of northwest quadrant of 40-acre site.

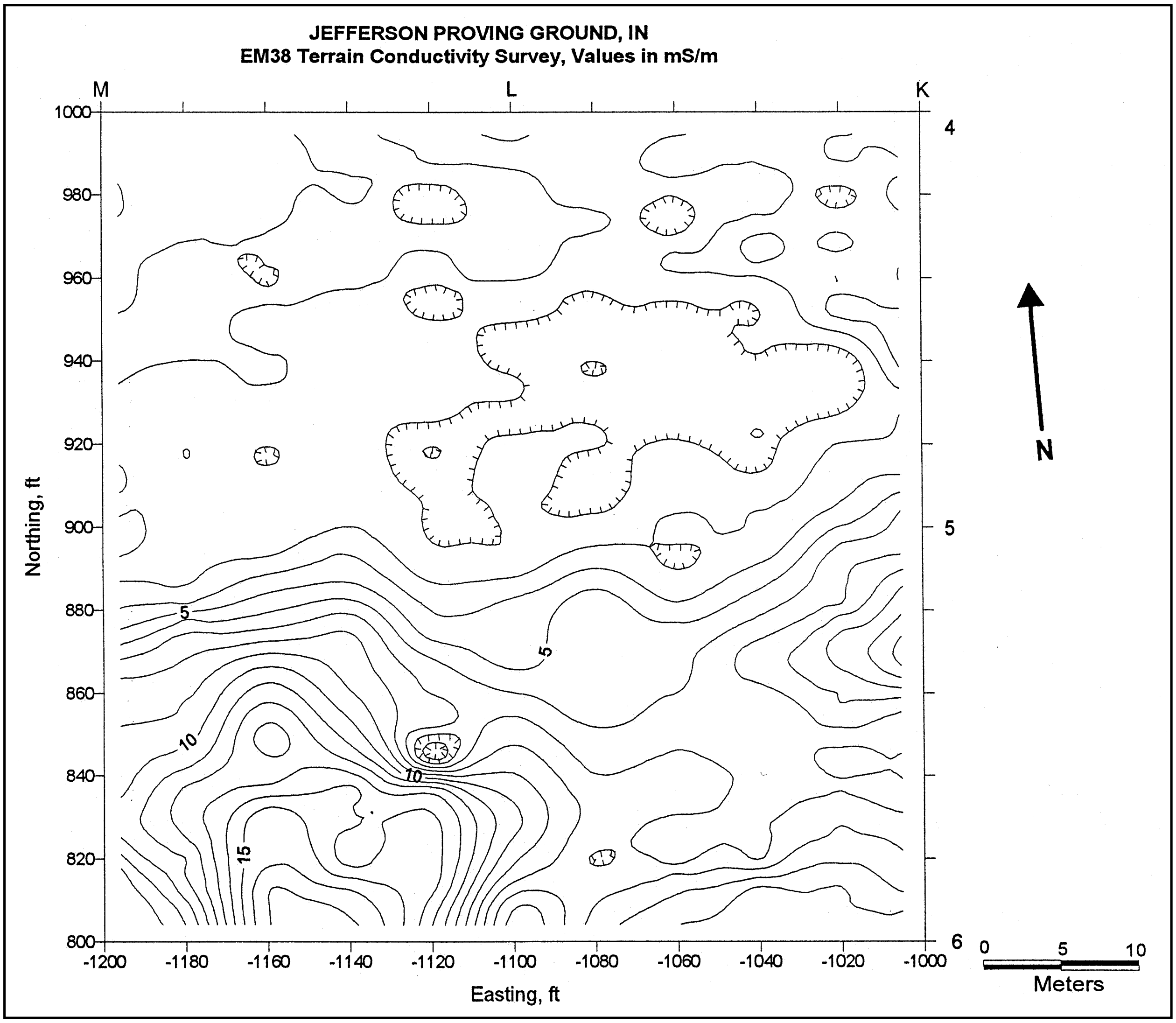

Figure 11. Terrain conductivity map determined with Geonics EM-38 (frequency domain EM induction system, 14.6 kHz) of a portion of the northwest quadrant of the 40-acre site, approximately centered on the anomalous magnetic feature shown in Figure 10

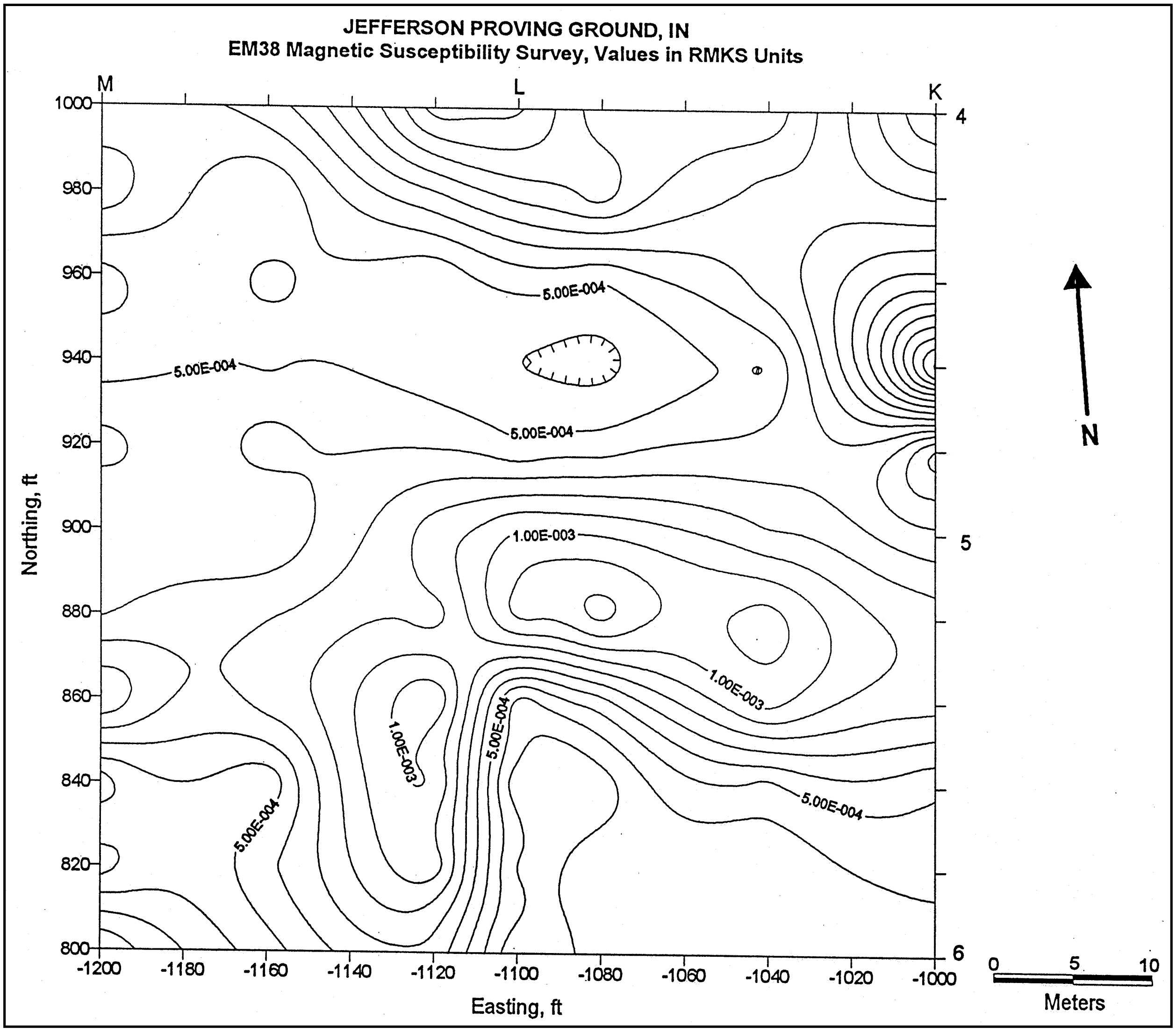

Figure 12. Magnetic susceptibility map (SI units) of a portion of the northwest quadrant of the 40-acre site, corresponding to the area shown in Figure 11 and approximately centered on the anomalous magnetic feature shown in Figure 10

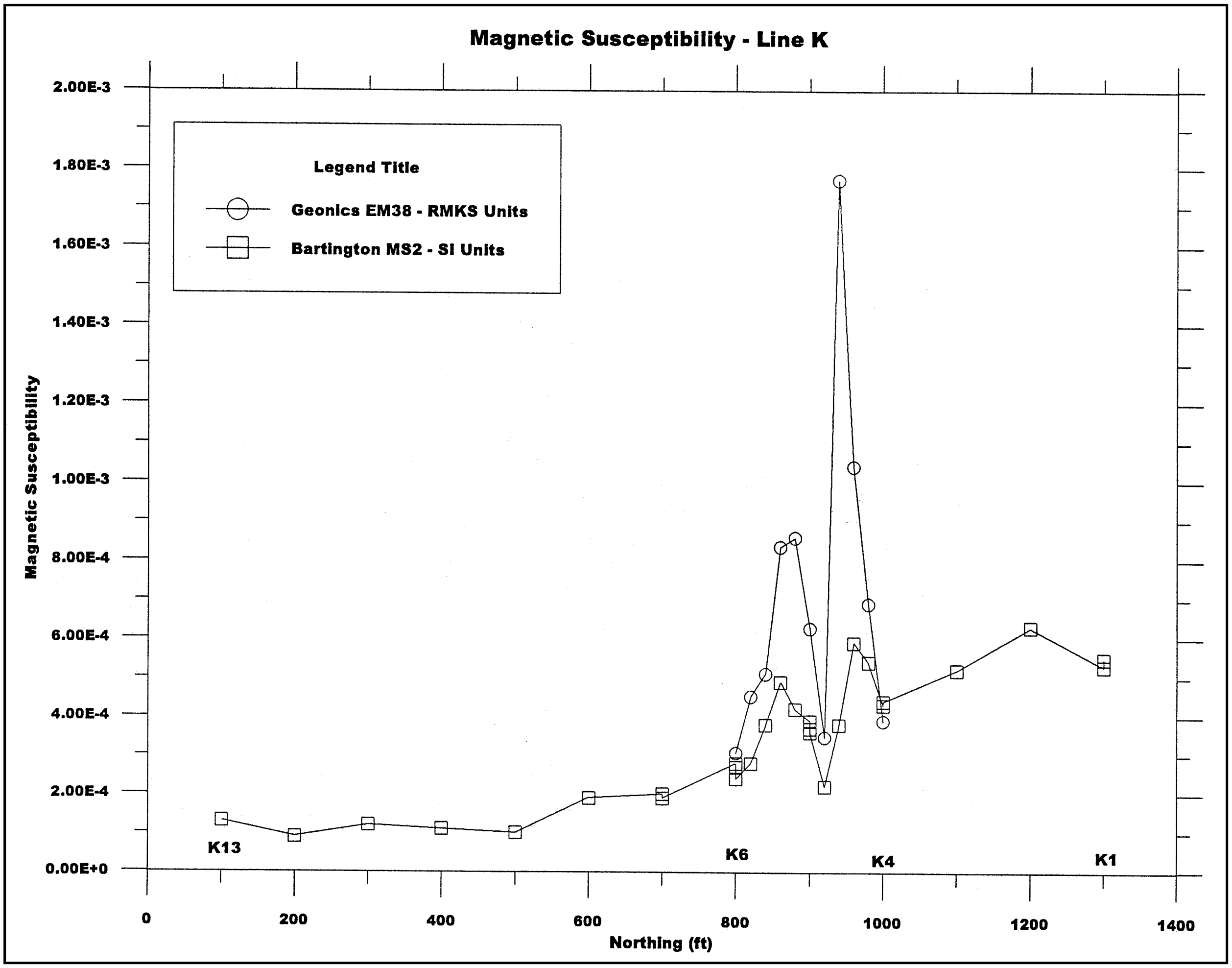

Figure 13. Magnetic susceptibility profiles along grid line K, from K13 to K1

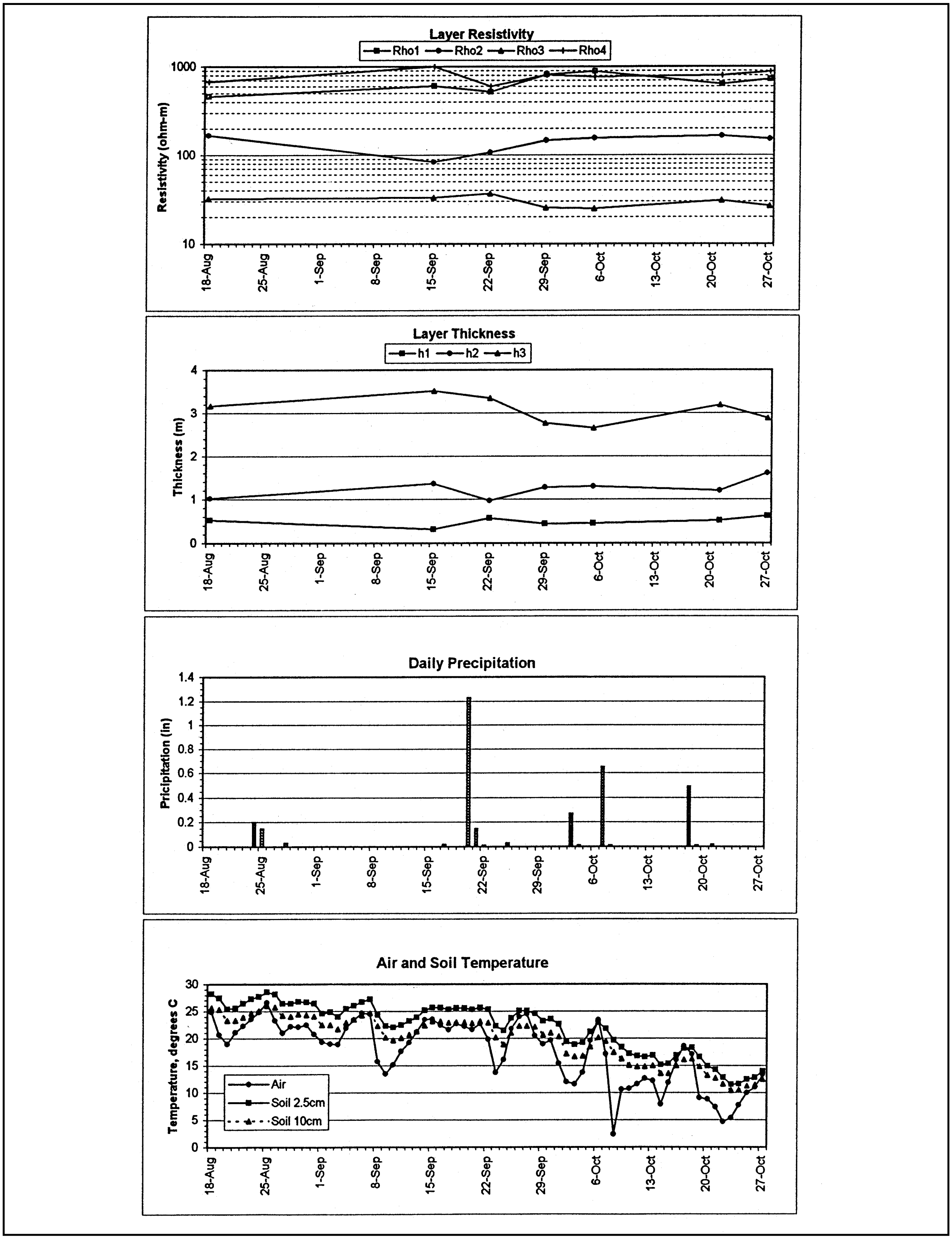

Figure 14. Electrical resistivity model parameters, percipitation, and air and soil temperature as a function of date during the Phase IV demonstrations

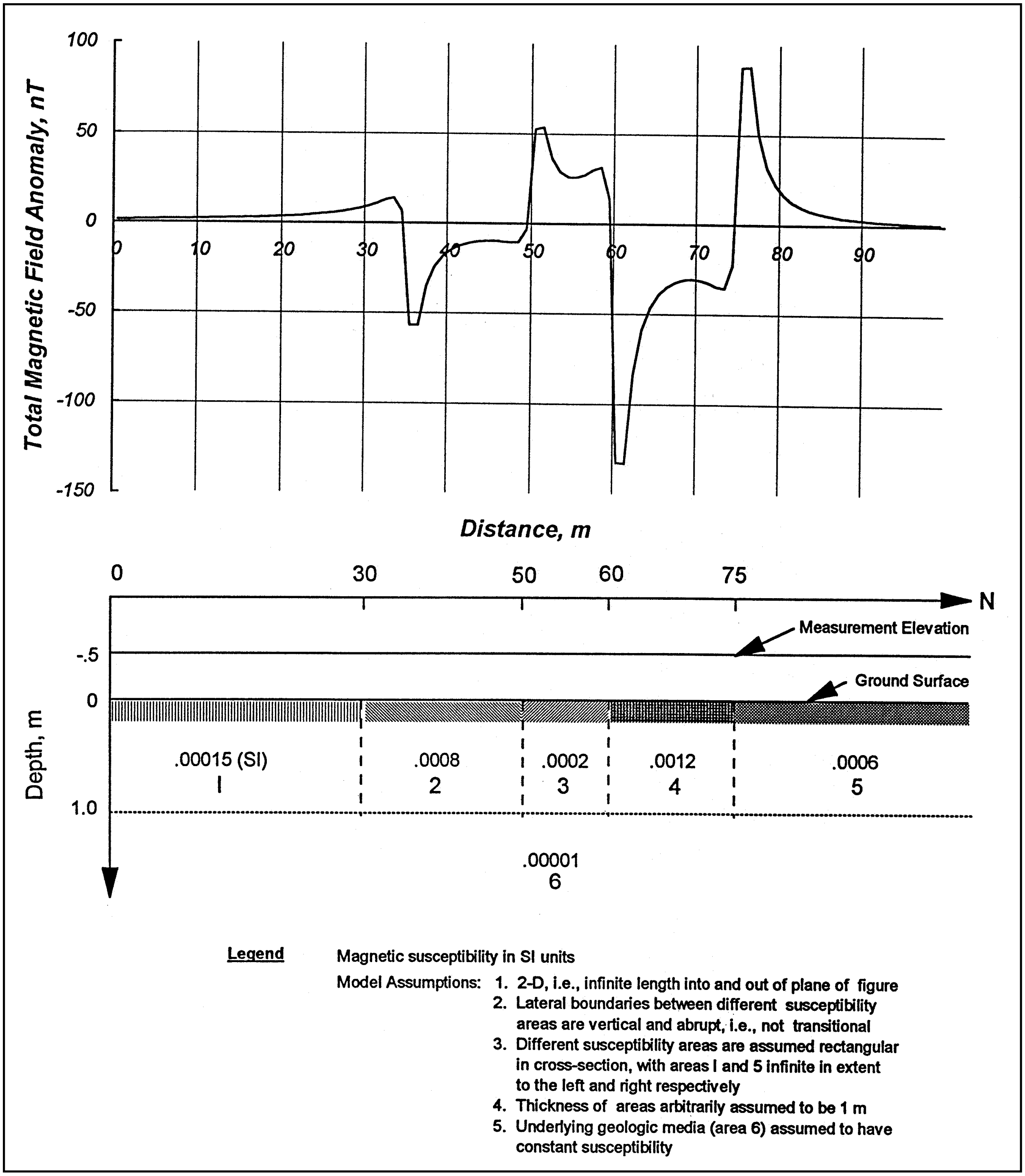

Figure 15. Total magnetic field anomaly calculations (2-D) for hypothetical model of susceptibility along line K based on susceptibility measurements (Figure 13)